FIG.1

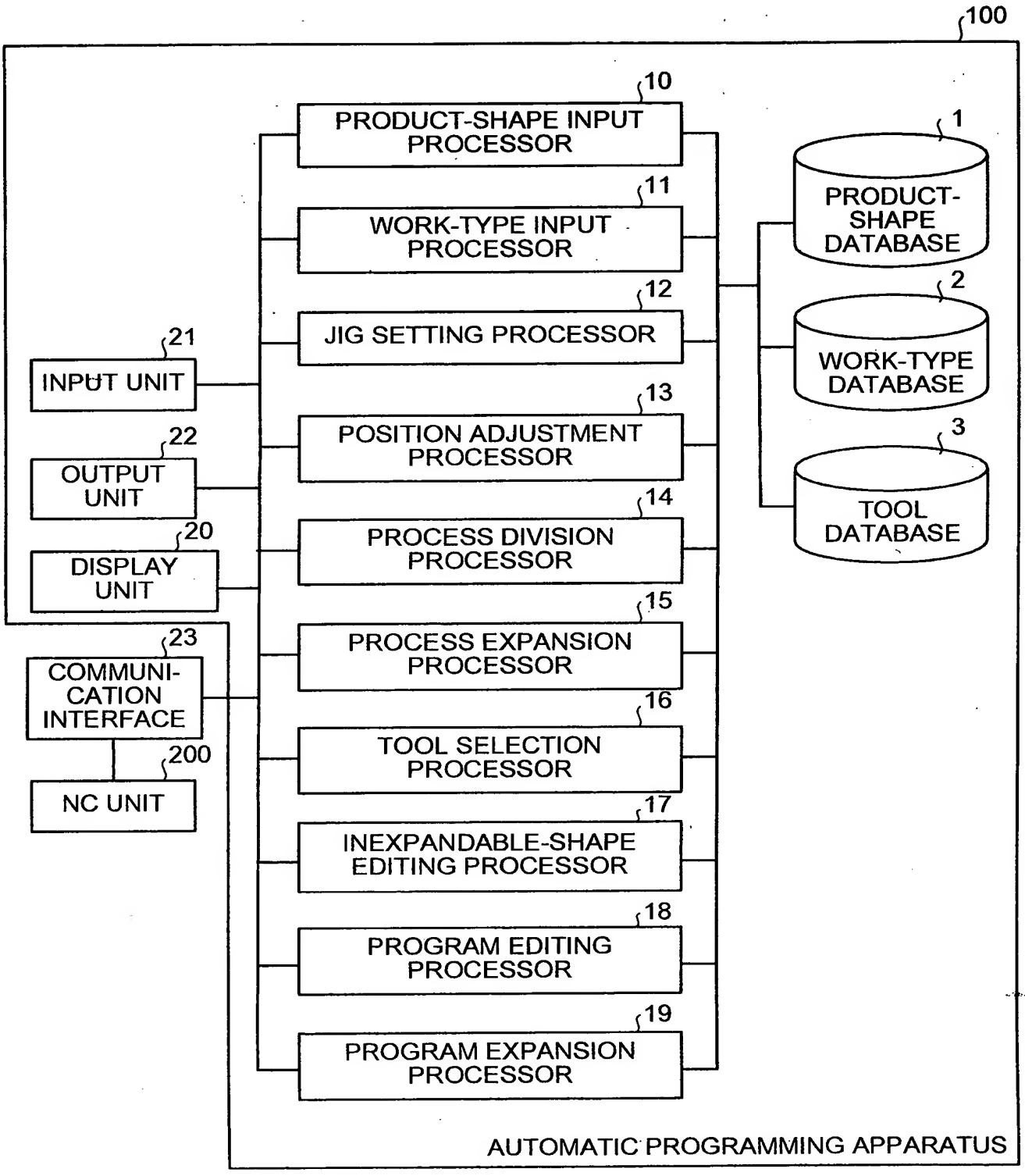
100
10
PRODUCT-SHAPE INPUT PROCESSOR
11
WORK-TYPE INPUT PROCESSOR
12
JIG SETTING PROCESSOR
13
POSITION ADJUSTMENT PROCESSOR
14
PROCESS DIVISION PROCESSOR
15
PROCESS EXPANSION PROCESSOR
16
TOOL SELECTION PROCESSOR
17
INEXPANDABLE-SHAPE EDITING PROCESSOR
18
PROGRAM EDITING PROCESSOR
19
PROGRAM EXPANSION PROCESSOR
1
PRODUCT-SHAPE DATABASE
2
WORK-TYPE DATABASE
3
TOOL DATABASE
21
INPUT UNIT
22
OUTPUT UNIT
20
DISPLAY UNIT
23
COMMUNI-CATION INTERFACE
200
NC UNIT
AUTOMATIC PROGRAMMING APPARATUS

FIG.2

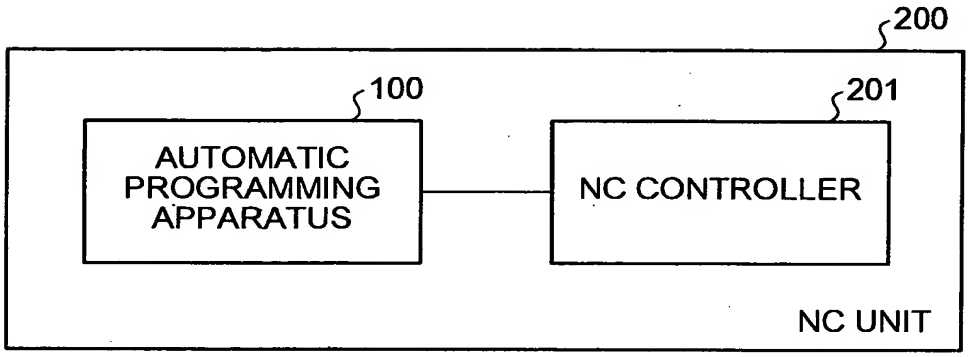
200
100
201
AUTOMATIC PROGRAMMING APPARATUS
NC CONTROLLER
NC UNIT

FIG.3

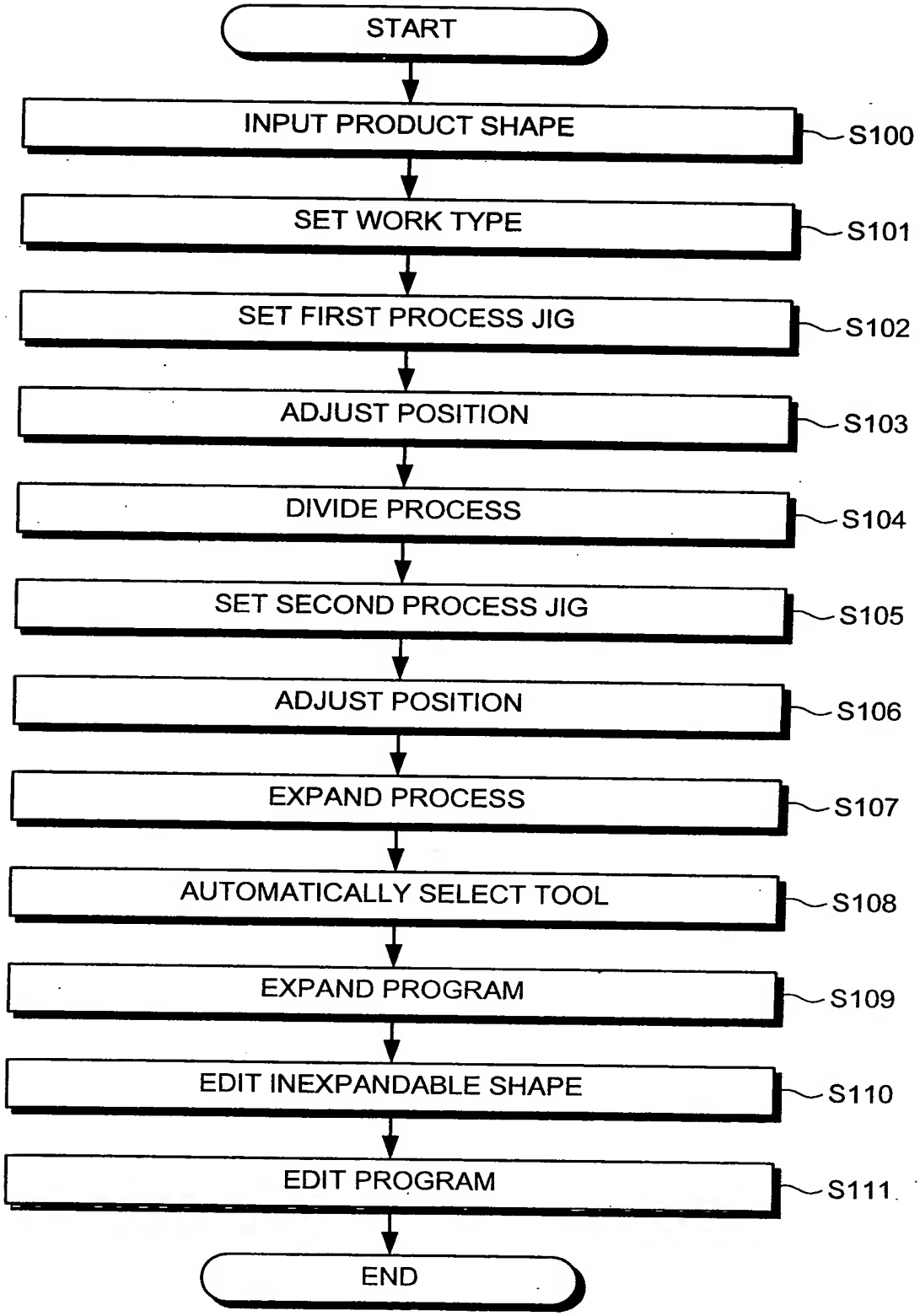
START
INPUT PRODUCT SHAPE
S100
SET WORK TYPE
S101
SET FIRST PROCESS JIG
S102
ADJUST POSITION
S103
DIVIDE PROCESS
S104
SET SECOND PROCESS JIG
S105
ADJUST POSITION
S106
EXPAND PROCESS
S107
AUTOMATICALLY SELECT TOOL
S108
EXPAND PROGRAM
S109
EDIT INEXPANDABLE SHAPE
S110
EDIT PROGRAM
S111
END

FIG.4

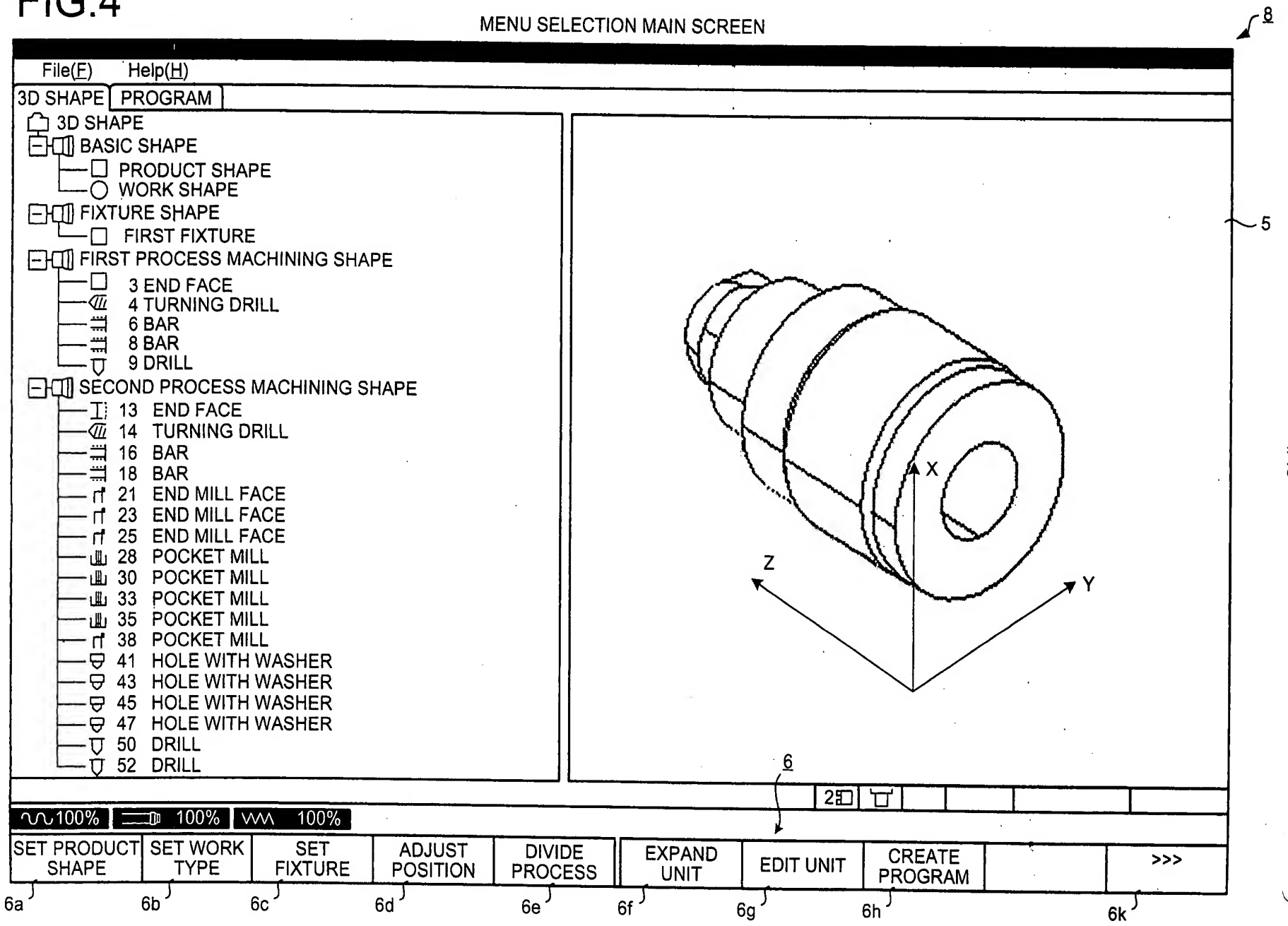

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FIG.5

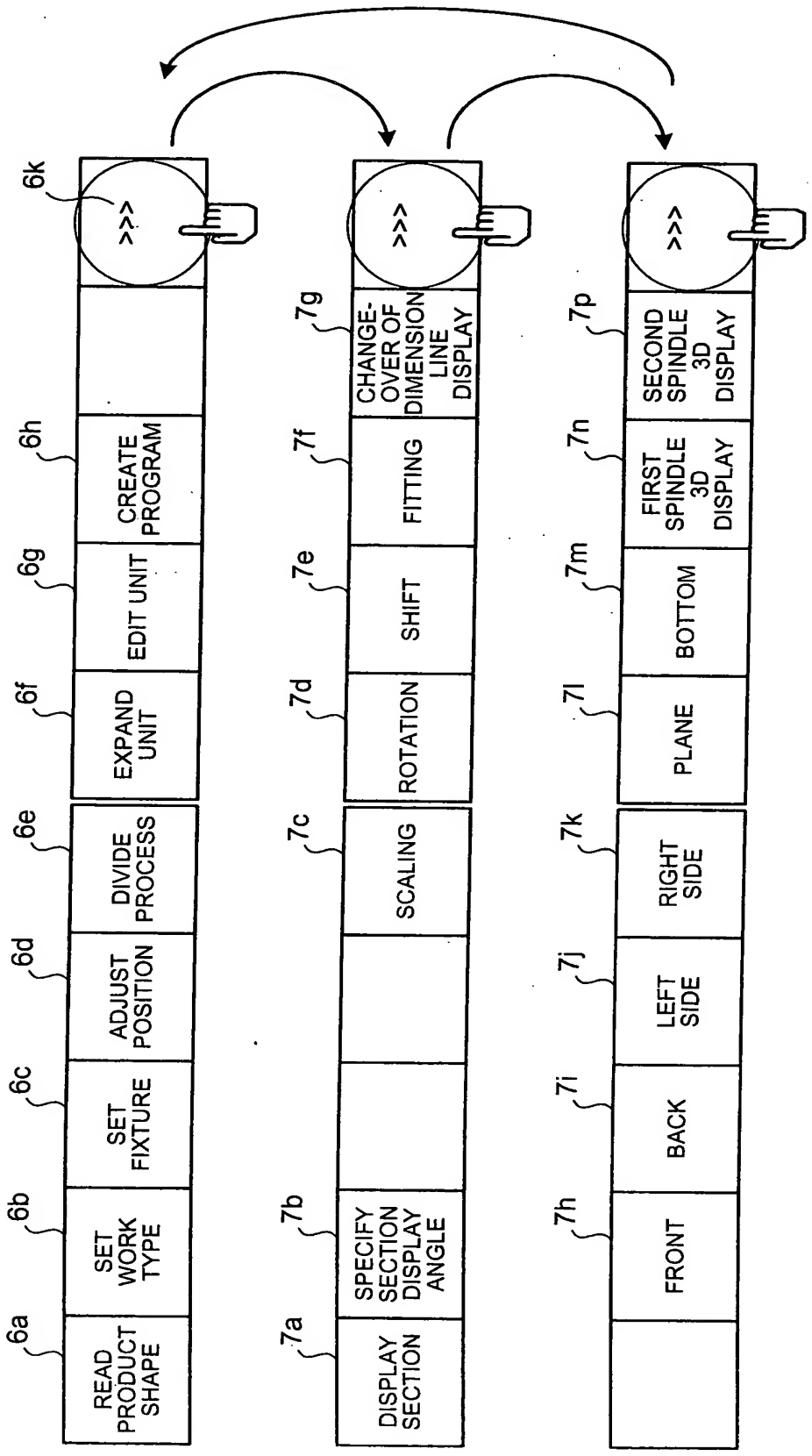
6k
>>>
6h
CREATE PROGRAM
6g
EDIT UNIT
6f
EXPAND UNIT
6e
DIVIDE PROCESS
6d
ADJUST POSITION
6c
SET FIXTURE
6b
SET WORK TYPE
6a
READ PRODUCT SHAPE
7g
CHANGE-OVER OF DIMENSION LINE DISPLAY
7f
FITTING
7e
SHIFT
7d
ROTATION
7c
SCALING
7b
SPECIFY SECTION DISPLAY ANGLE
7a
DISPLAY SECTION
7p
SECOND SPINDLE 3D DISPLAY
7n
FIRST SPINDLE 3D DISPLAY
7m
BOTTOM
7l
PLANE
7k
RIGHT SIDE
7j
LEFT SIDE
7i
BACK
7h
FRONT

FIG.6

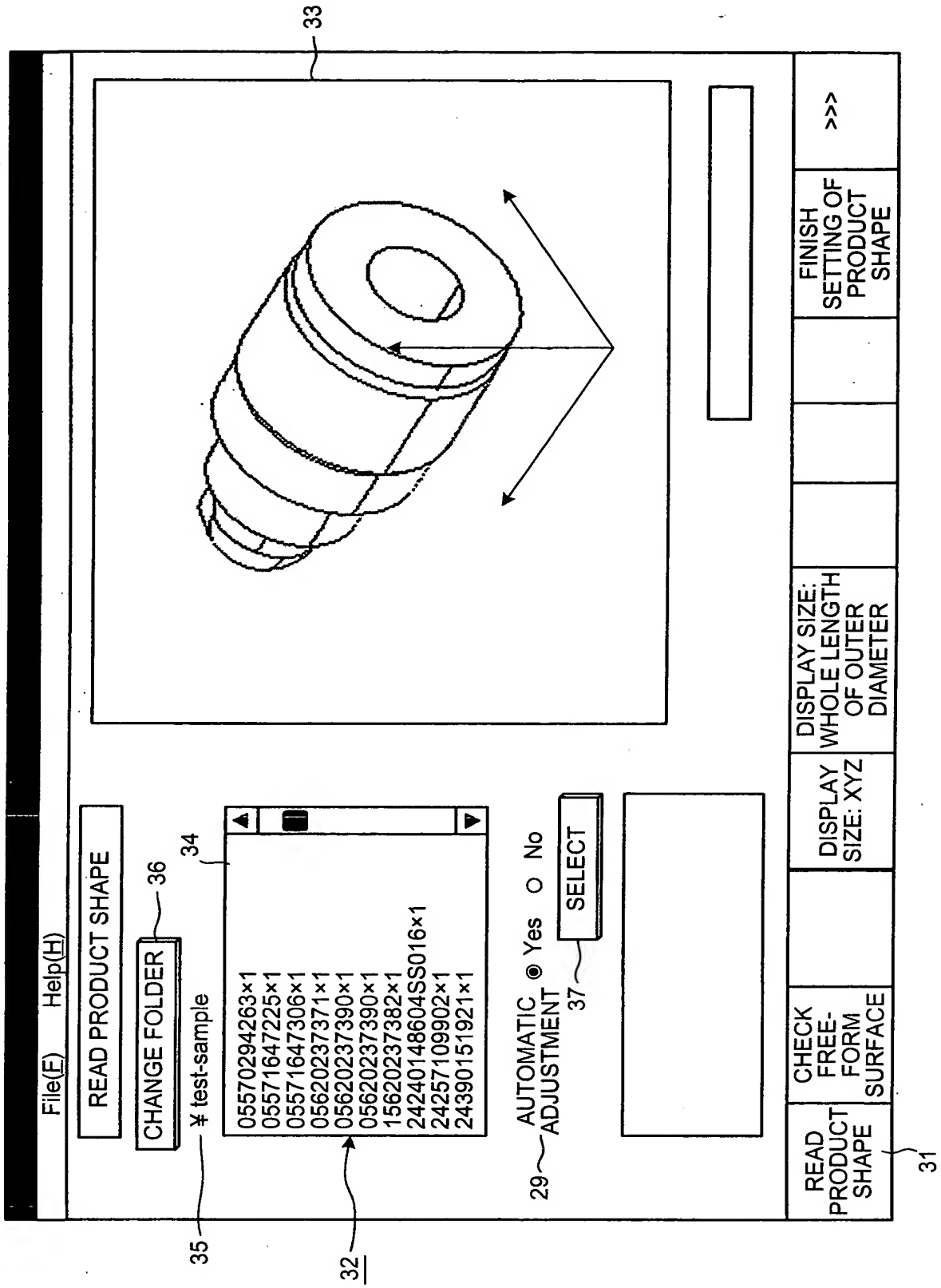
30
33
File(F)
Help(H)
READ PRODUCT SHAPE
CHANGE FOLDER
36
¥ test-sample
35
34
05570294263×1
05571647225×1
05571647306×1
05620237371×1
05620237390×1
05620237390×1
15620237382×1
24240148604SS016×1
24257109902×1
24390151921×1
32
AUTOMATIC ADJUSTMENT
Yes
No
29
SELECT
37
READ PRODUCT SHAPE
CHECK FREE-FORM SURFACE
DISPLAY SIZE: XYZ
DISPLAY SIZE: WHOLE LENGTH OF OUTER DIAMETER
FINISH SETTING OF PRODUCT SHAPE
>>>
31

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FIG.7

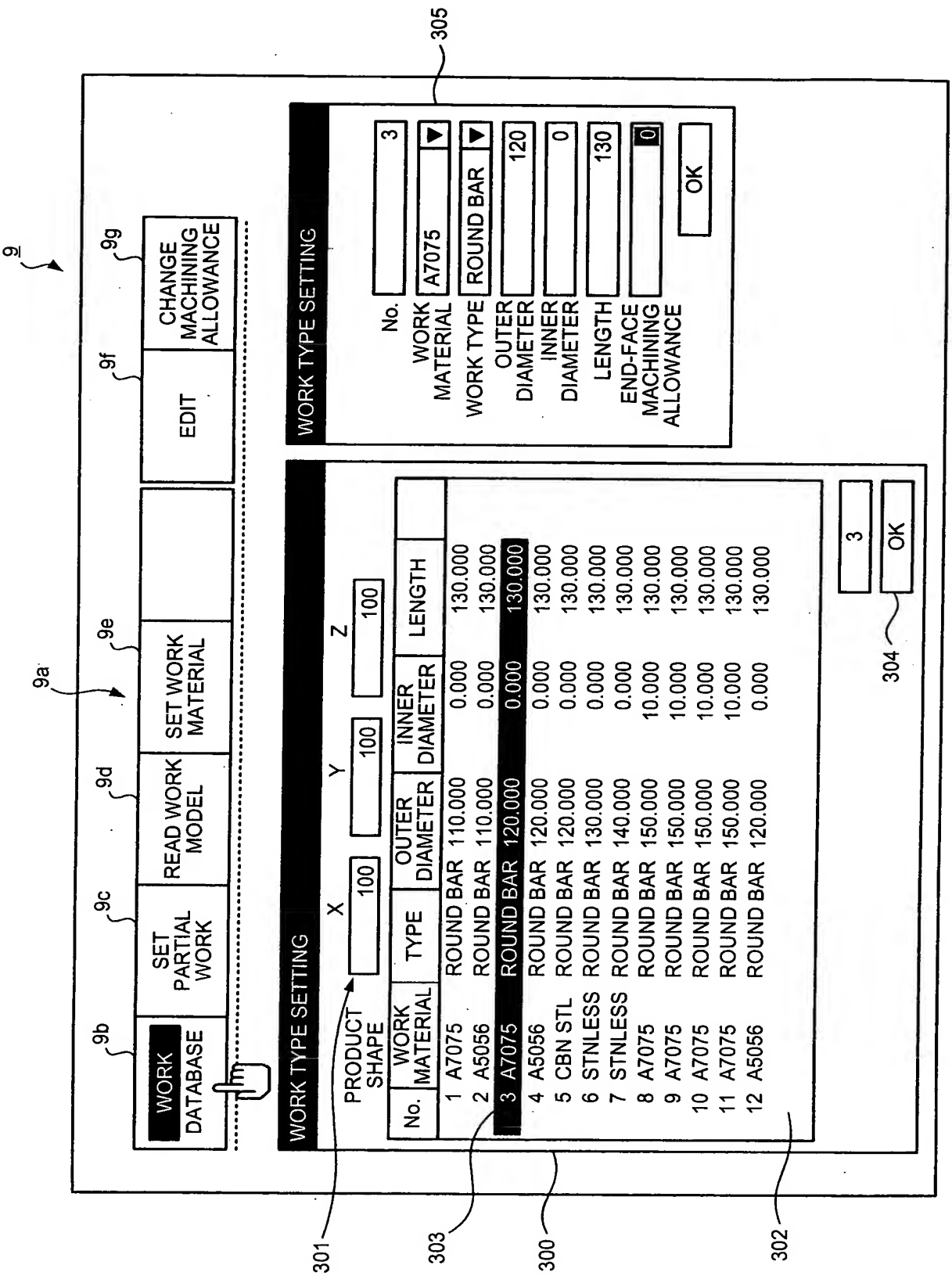

FIG.8

WORK SHAPE

MATERIAL	TYPE	OUTER DIAMETER	INNER DIAMETER	. . . . .
CBN STL	Cylinder	250	20	
CBN STL	Cylinder	250	30	
CBN STL	Cylinder	250	40	
CBN STL	Cylinder	250	50	
CBN STL	Cylinder	400		
CBN STL	Cylinder	400	30	
CBN STL	Cylinder	500		
CBN STL	Cylinder	800	70	
CBN STL	Cylinder	800	100	
CBN STL	Hexagon	300		
CBN STL	Hexagon	300		
CBN STL	Hexagon	400		

FIG.9

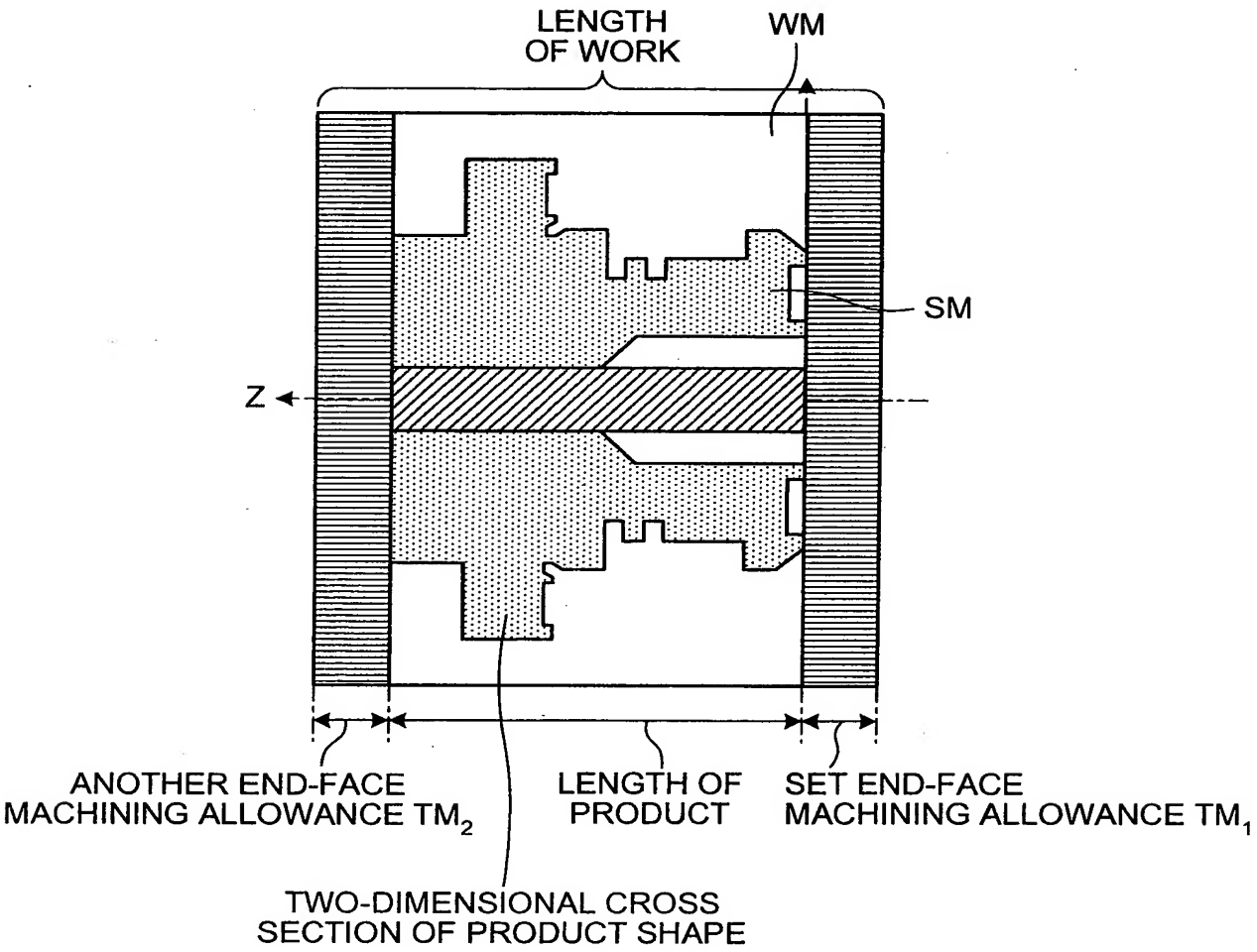
LENGTH OF WORK
WM
SM
Z
ANOTHER END-FACE MACHINING ALLOWANCE TM_2
LENGTH OF PRODUCT
SET END-FACE MACHINING ALLOWANCE TM_1
TWO-DIMENSIONAL CROSS SECTION OF PRODUCT SHAPE

FIG.10

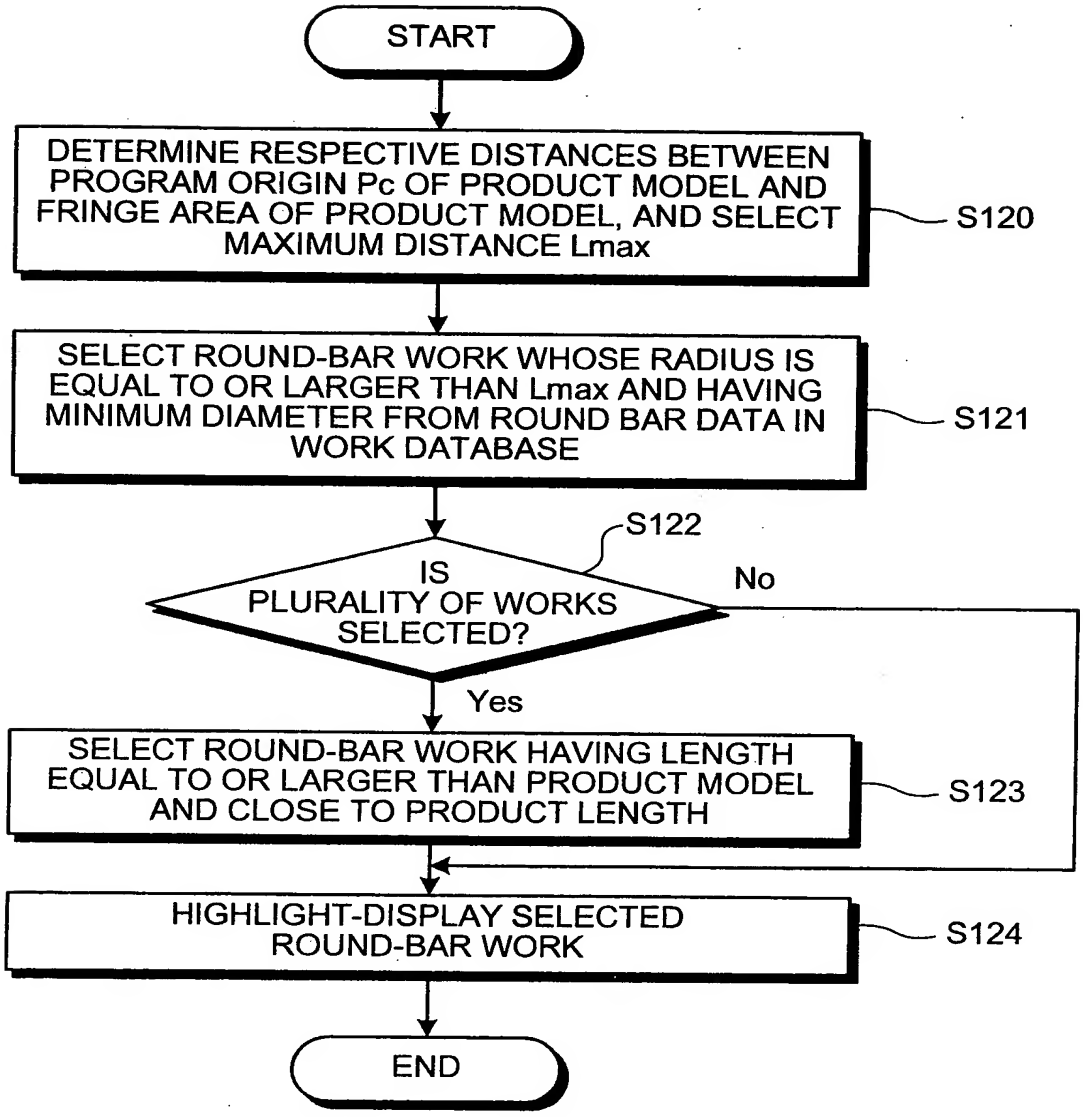
START
DETERMINE RESPECTIVE DISTANCES BETWEEN PROGRAM ORIGIN Pc OF PRODUCT MODEL AND FRINGE AREA OF PRODUCT MODEL, AND SELECT MAXIMUM DISTANCE Lmax
S120
SELECT ROUND-BAR WORK WHOSE RADIUS IS EQUAL TO OR LARGER THAN Lmax AND HAVING MINIMUM DIAMETER FROM ROUND BAR DATA IN WORK DATABASE
S121
S122
IS PLURALITY OF WORKS SELECTED?
No
Yes
SELECT ROUND-BAR WORK HAVING LENGTH EQUAL TO OR LARGER THAN PRODUCT MODEL AND CLOSE TO PRODUCT LENGTH
S123
HIGHLIGHT-DISPLAY SELECTED ROUND-BAR WORK
S124
END

FIG.11

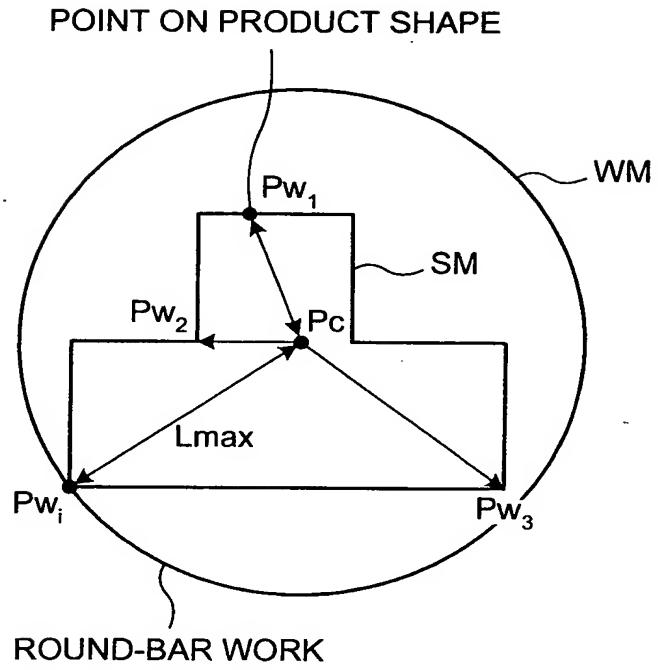
POINT ON PRODUCT SHAPE
WM
Pw1
SM
Pw2
Pc
Lmax
Pwi
Pw3
ROUND-BAR WORK

FIG.12

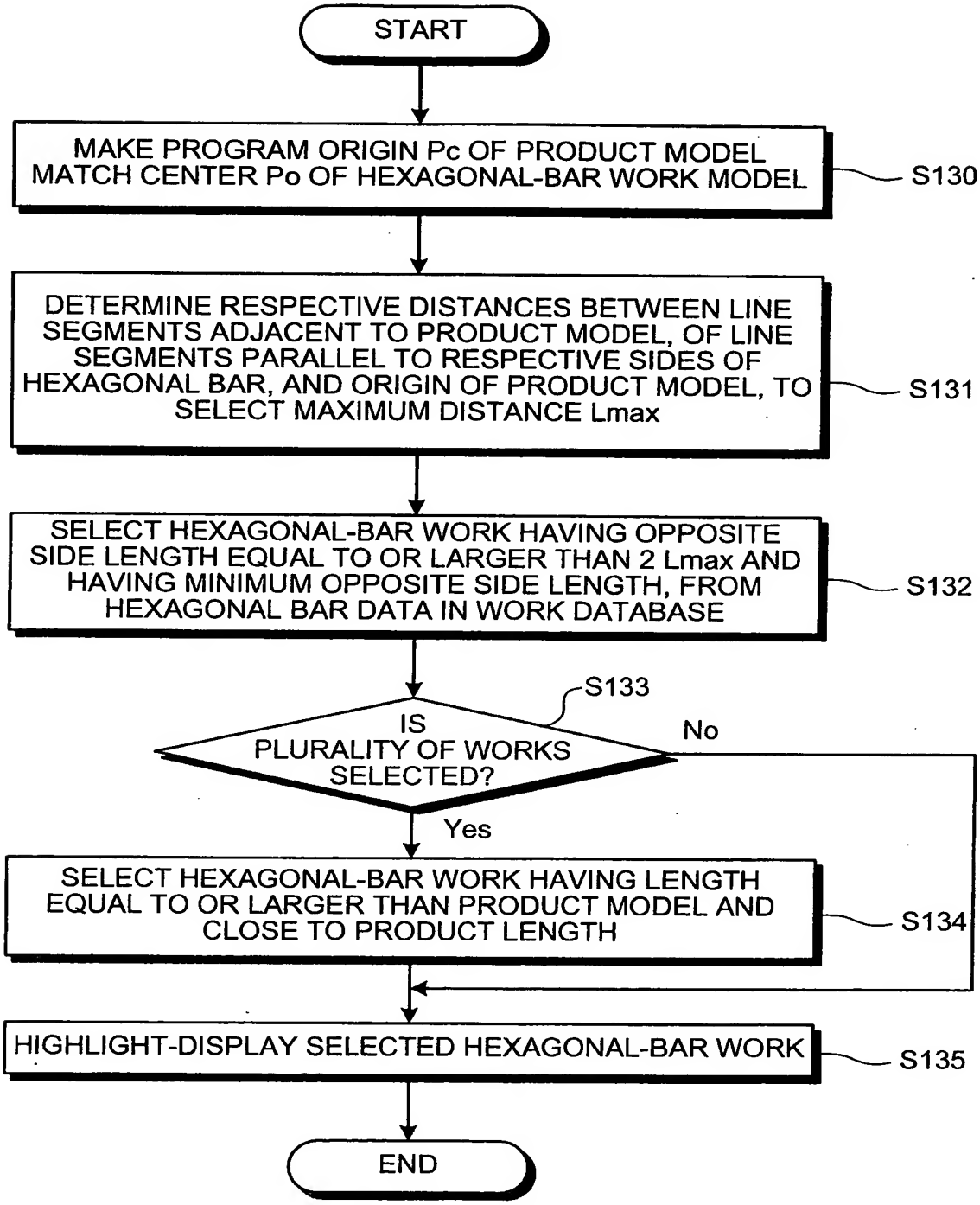
START
MAKE PROGRAM ORIGIN Pc OF PRODUCT MODEL MATCH CENTER Po OF HEXAGONAL-BAR WORK MODEL
S130
DETERMINE RESPECTIVE DISTANCES BETWEEN LINE SEGMENTS ADJACENT TO PRODUCT MODEL, OF LINE SEGMENTS PARALLEL TO RESPECTIVE SIDES OF HEXAGONAL BAR, AND ORIGIN OF PRODUCT MODEL, TO SELECT MAXIMUM DISTANCE Lmax
S131
SELECT HEXAGONAL-BAR WORK HAVING OPPOSITE SIDE LENGTH EQUAL TO OR LARGER THAN 2 Lmax AND HAVING MINIMUM OPPOSITE SIDE LENGTH, FROM HEXAGONAL BAR DATA IN WORK DATABASE
S132
S133
IS PLURALITY OF WORKS SELECTED?
No
Yes
SELECT HEXAGONAL-BAR WORK HAVING LENGTH EQUAL TO OR LARGER THAN PRODUCT MODEL AND CLOSE TO PRODUCT LENGTH
S134
HIGHLIGHT-DISPLAY SELECTED HEXAGONAL-BAR WORK
S135
END

FIG.13

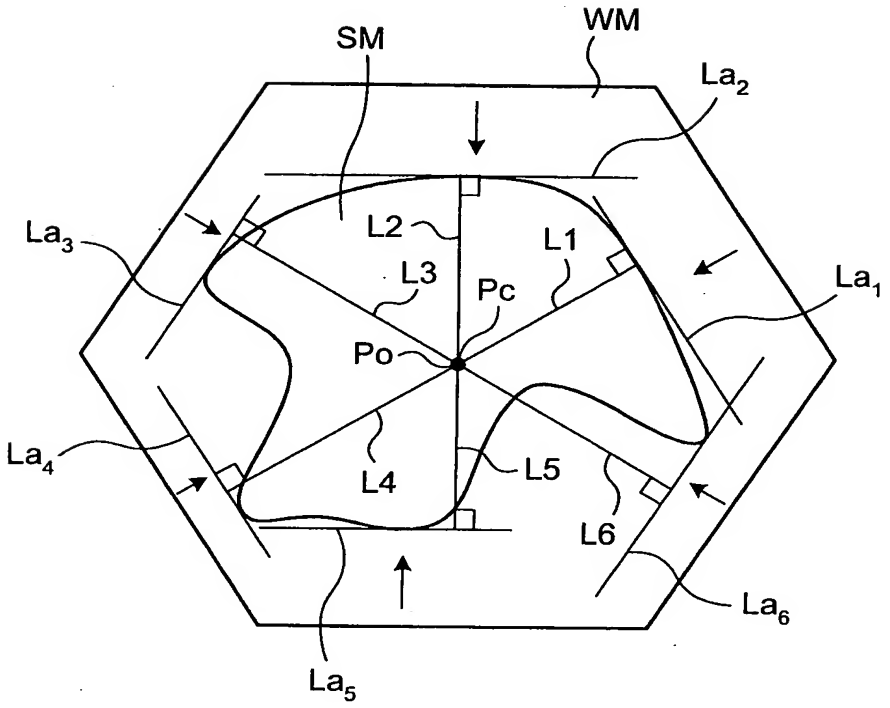

FIG.14

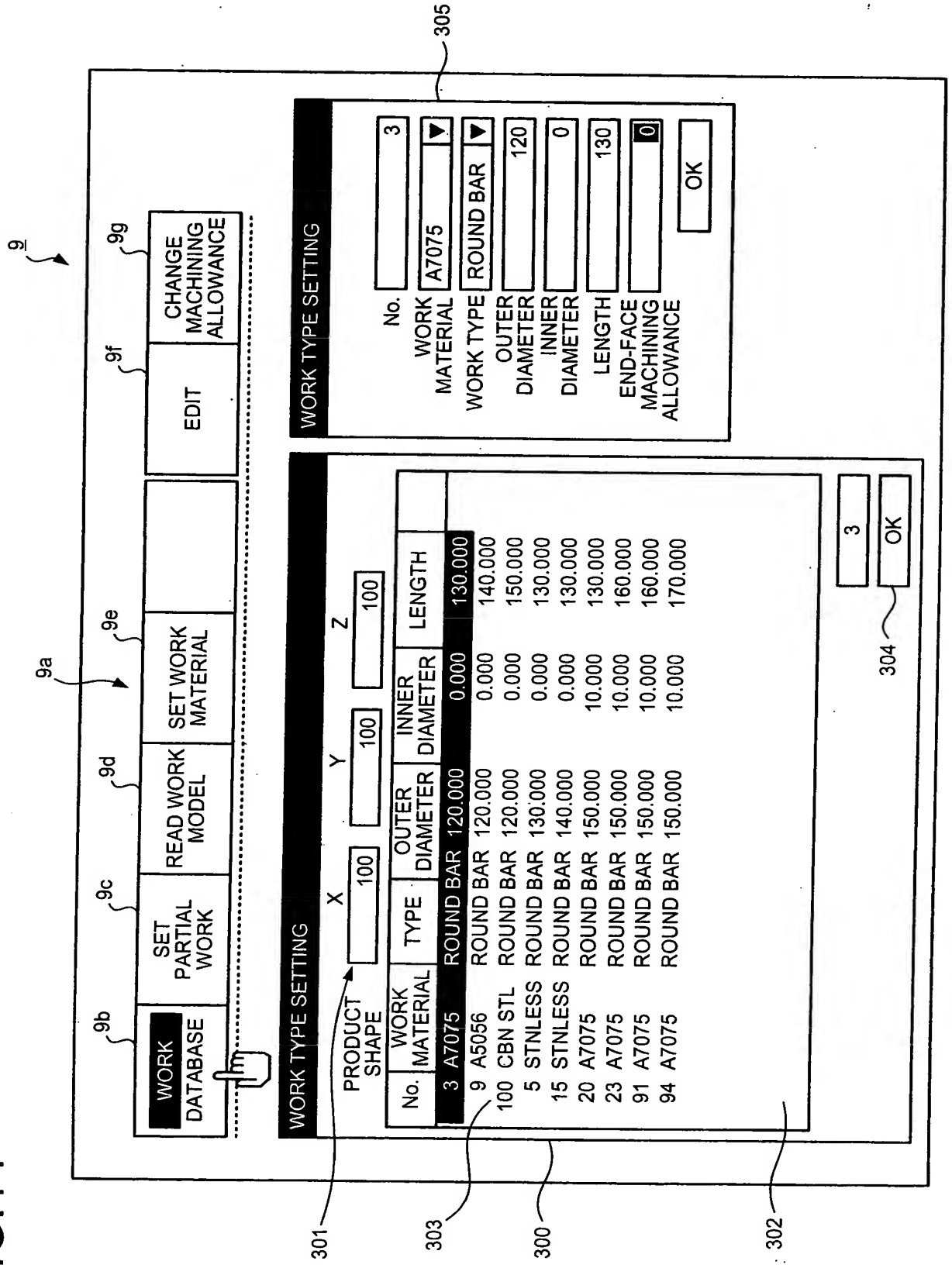
9
9a
9b
WORK DATABASE
9c
SET PARTIAL WORK
9d
READ WORK MODEL
9e
SET WORK MATERIAL
9f
EDIT
9g
CHANGE MACHINING ALLOWANCE
305
WORK TYPE SETTING
No. 3
WORK MATERIAL A7075
WORK TYPE ROUND BAR
OUTER DIAMETER 120
INNER DIAMETER 0
LENGTH 130
END-FACE MACHINING ALLOWANCE 0
OK
WORK TYPE SETTING
PRODUCT SHAPE
X 100
Y 100
Z 100
No. WORK MATERIAL TYPE OUTER DIAMETER INNER DIAMETER LENGTH
3 A7075 ROUND BAR 120.000 0.000 130.000
9 A5056 ROUND BAR 120.000 0.000 140.000
100 CBN STL ROUND BAR 120.000 0.000 150.000
5 STNLESS ROUND BAR 130.000 0.000 130.000
15 STNLESS ROUND BAR 140.000 0.000 130.000
20 A7075 ROUND BAR 150.000 10.000 130.000
23 A7075 ROUND BAR 150.000 10.000 160.000
91 A7075 ROUND BAR 150.000 10.000 160.000
94 A7075 ROUND BAR 150.000 10.000 170.000
3
OK
304
301
303
300
302

FIG.15

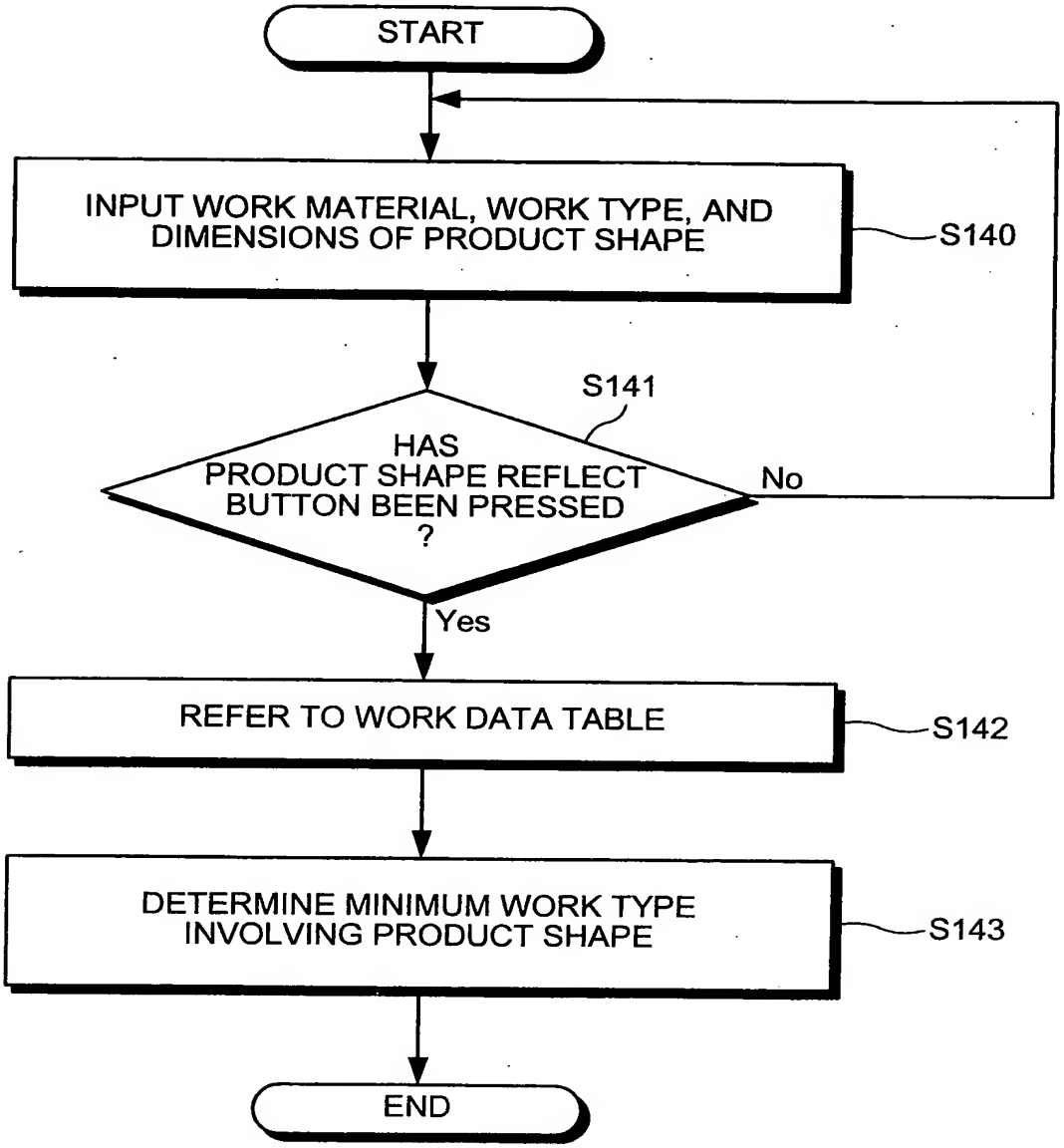
START
INPUT WORK MATERIAL, WORK TYPE, AND DIMENSIONS OF PRODUCT SHAPE
S140
S141
HAS PRODUCT SHAPE REFLECT BUTTON BEEN PRESSED ?
No
Yes
REFER TO WORK DATA TABLE
S142
DETERMINE MINIMUM WORK TYPE INVOLVING PRODUCT SHAPE
S143
END

FIG.16

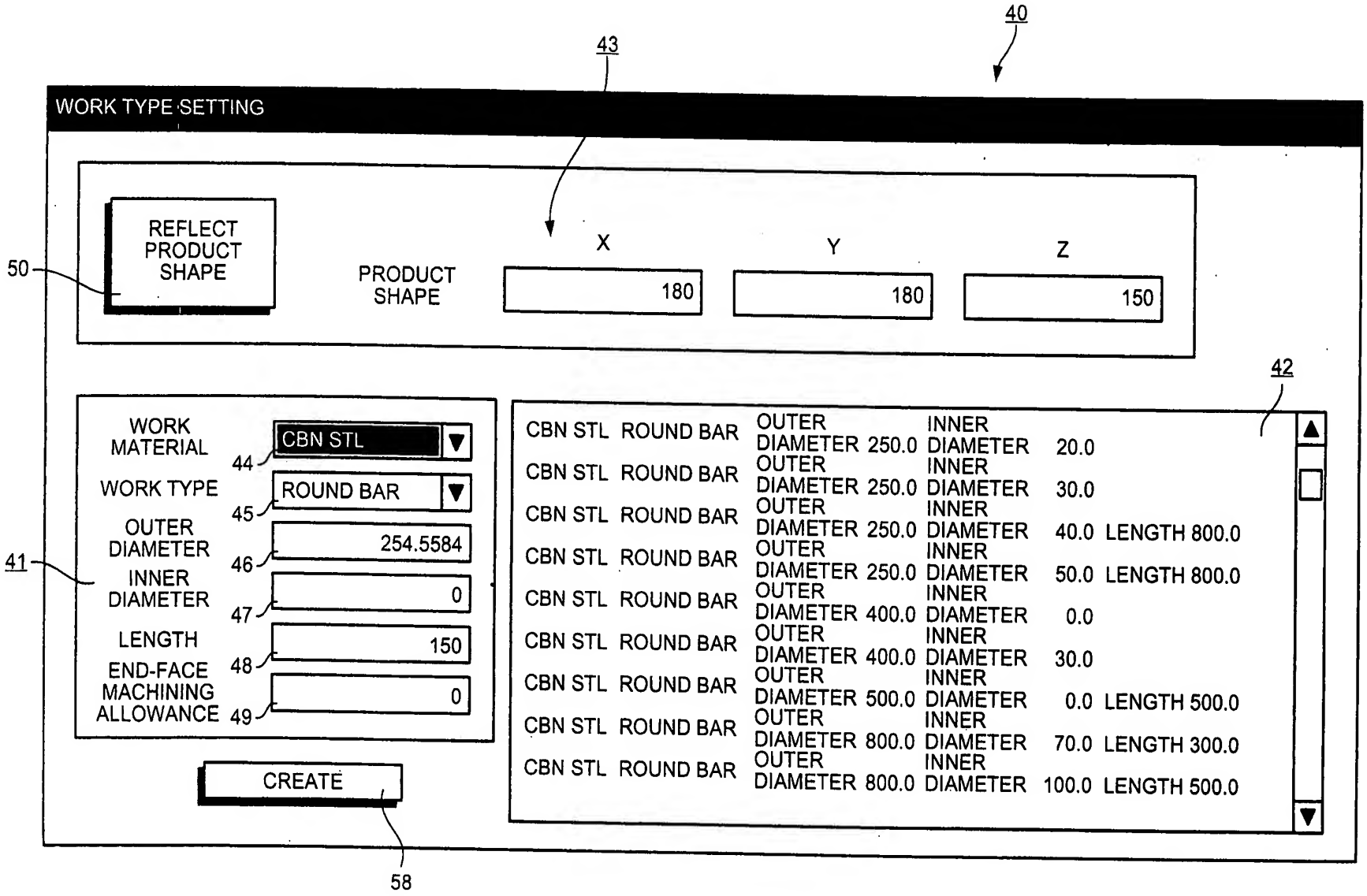

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FIG.17

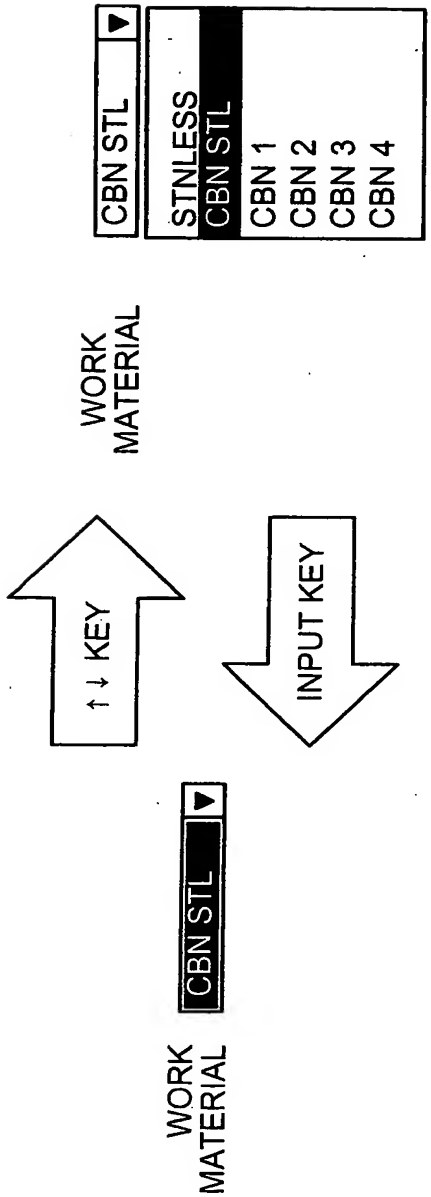
CBN STL
STNLESS
CBN STL
CBN 1
CBN 2
CBN 3
CBN 4
WORK MATERIAL
↑↓ KEY
INPUT KEY
CBN STL
WORK MATERIAL

FIG.18

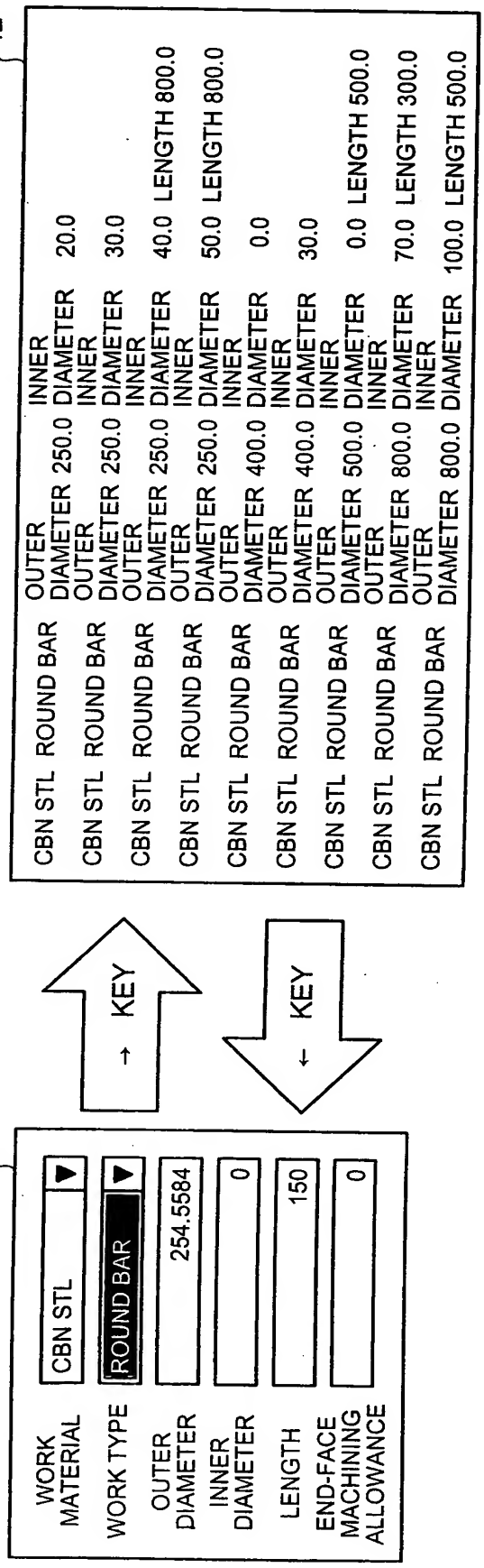
42
CBN STL ROUND BAR OUTER DIAMETER 250.0 INNER DIAMETER 20.0
CBN STL ROUND BAR OUTER DIAMETER 250.0 INNER DIAMETER 30.0
CBN STL ROUND BAR OUTER DIAMETER 250.0 INNER DIAMETER 40.0 LENGTH 800.0
CBN STL ROUND BAR OUTER DIAMETER 250.0 INNER DIAMETER 50.0 LENGTH 800.0
CBN STL ROUND BAR OUTER DIAMETER 400.0 INNER DIAMETER 0.0
CBN STL ROUND BAR OUTER DIAMETER 400.0 INNER DIAMETER 30.0
CBN STL ROUND BAR OUTER DIAMETER 500.0 INNER DIAMETER 0.0 LENGTH 500.0
CBN STL ROUND BAR OUTER DIAMETER 800.0 INNER DIAMETER 70.0 LENGTH 300.0
CBN STL ROUND BAR OUTER DIAMETER 800.0 INNER DIAMETER 100.0 LENGTH 500.0
↑ KEY
↓ KEY
41
WORK MATERIAL
CBN STL
WORK TYPE
ROUND BAR
OUTER DIAMETER
254.5584
INNER DIAMETER
0
LENGTH
150
END-FACE MACHINING ALLOWANCE
0

FIG.19

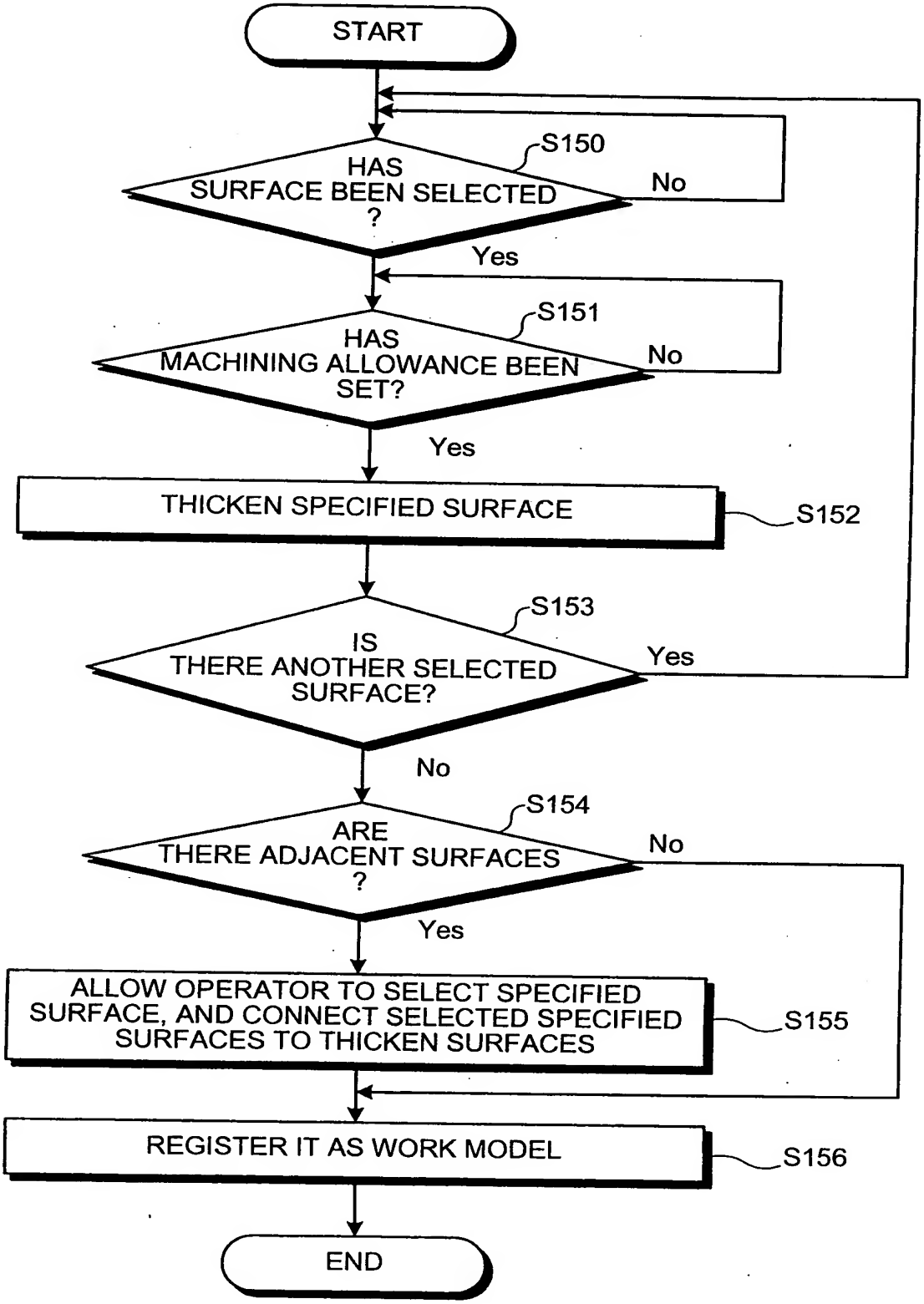
START
S150
HAS SURFACE BEEN SELECTED ?
No
Yes
S151
HAS MACHINING ALLOWANCE BEEN SET?
No
Yes
THICKEN SPECIFIED SURFACE
S152
S153
IS THERE ANOTHER SELECTED SURFACE?
Yes
No
S154
ARE THERE ADJACENT SURFACES ?
No
Yes
ALLOW OPERATOR TO SELECT SPECIFIED SURFACE, AND CONNECT SELECTED SPECIFIED SURFACES TO THICKEN SURFACES
S155
REGISTER IT AS WORK MODEL
S156
END

FIG.20

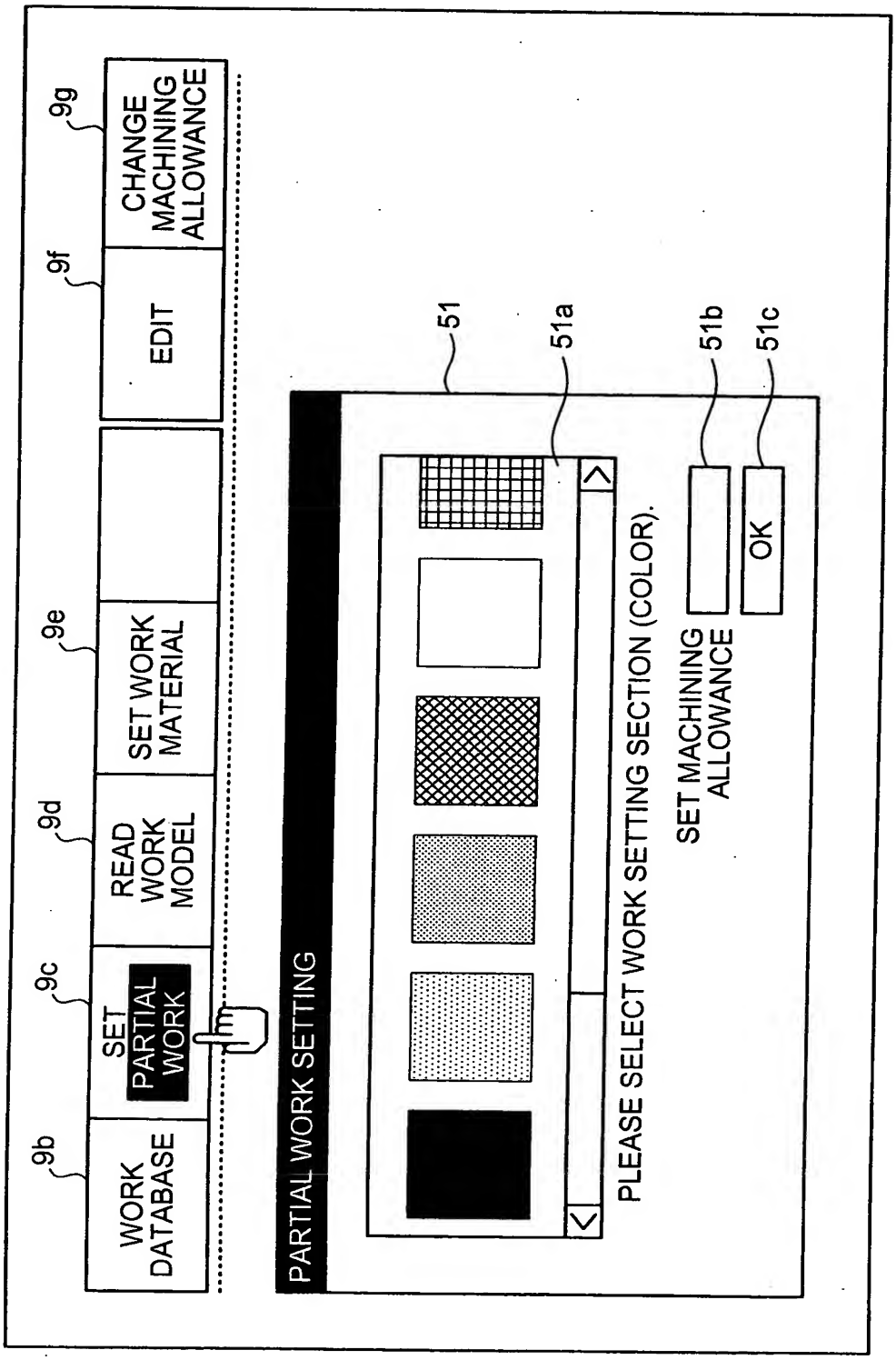
9b
WORK DATABASE
9c
SET PARTIAL WORK
9d
READ WORK MODEL
9e
SET WORK MATERIAL
9f
EDIT
9g
CHANGE MACHINING ALLOWANCE
PARTIAL WORK SETTING
51
51a
51b
51c
PLEASE SELECT WORK SETTING SECTION (COLOR).
SET MACHINING ALLOWANCE
OK

FIG.21

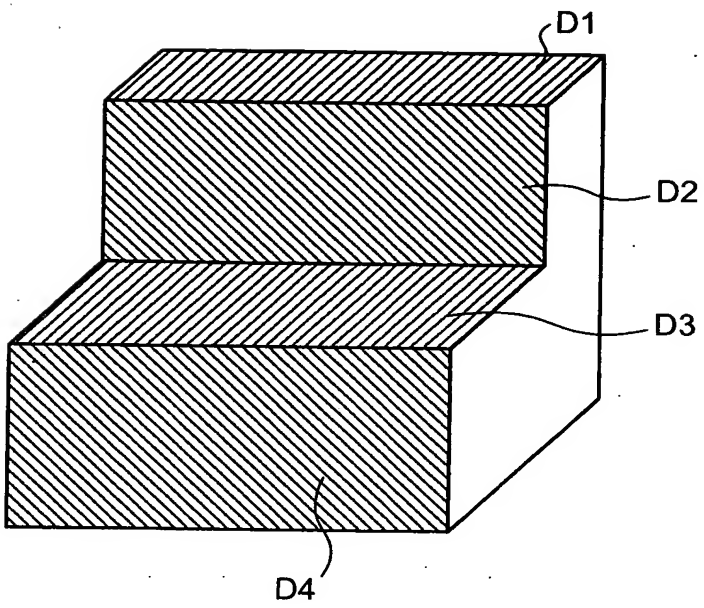

FIG.22

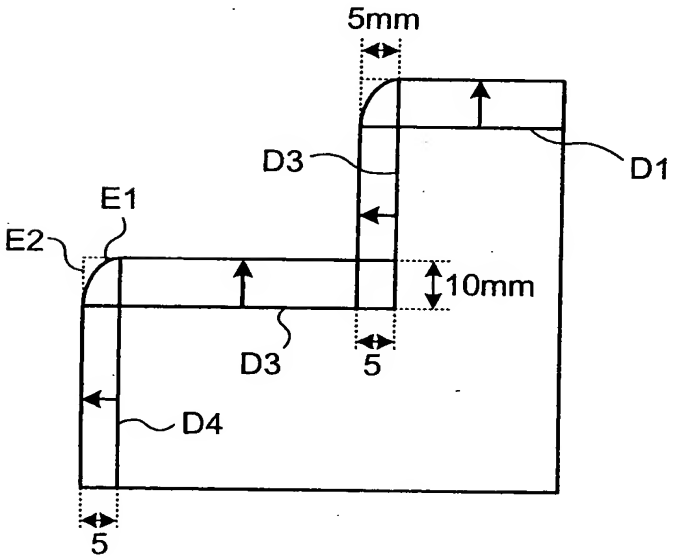

FIG.23

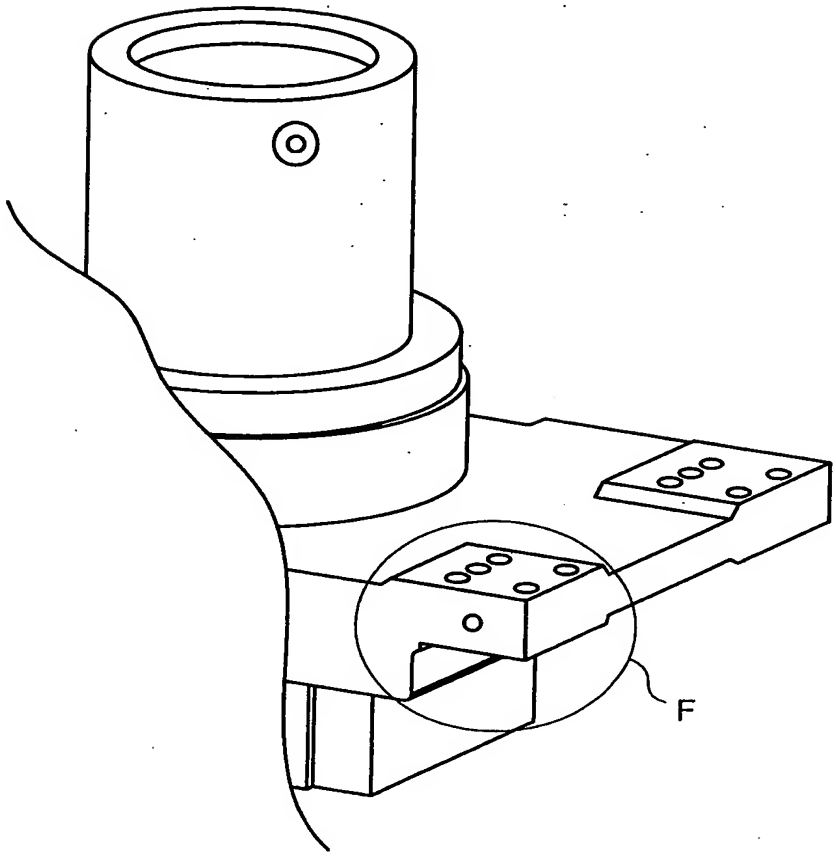

FIG.24

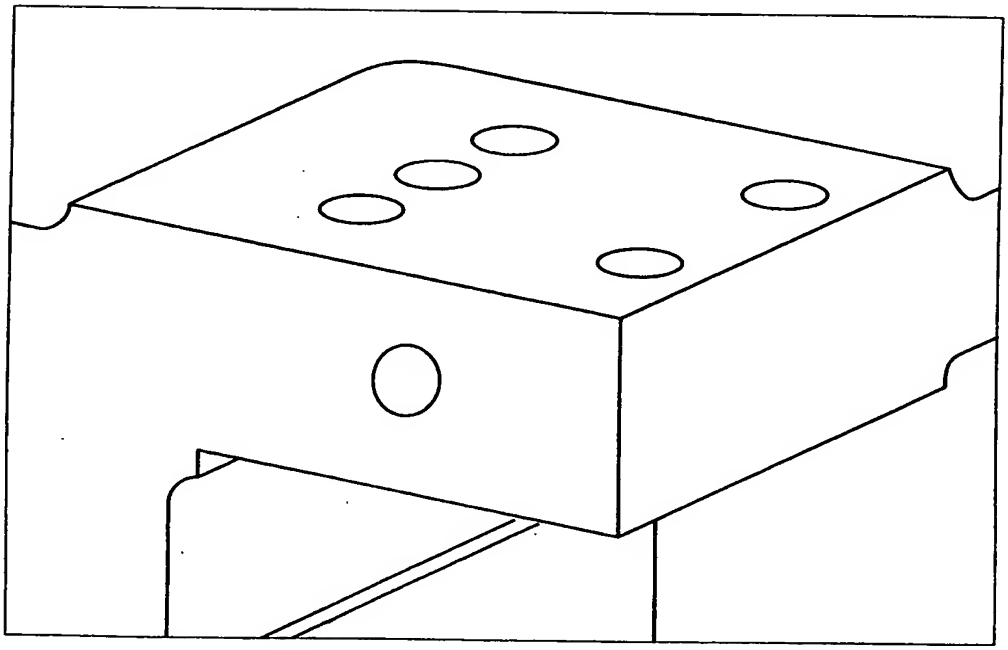

FIG.25

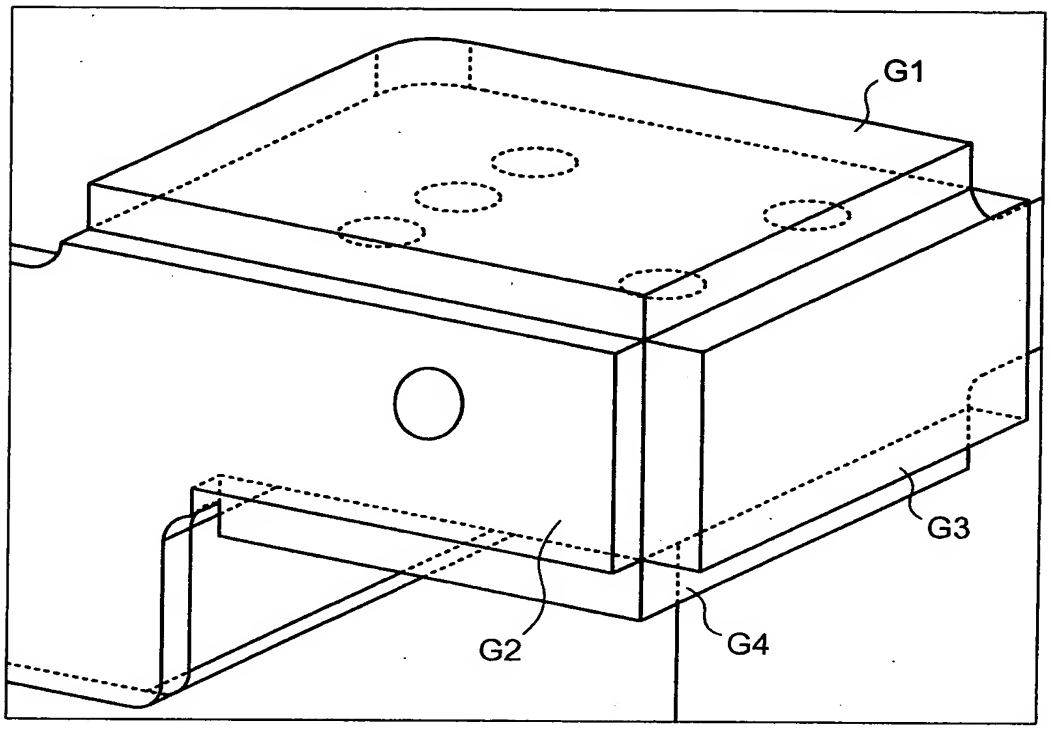

FIG.26

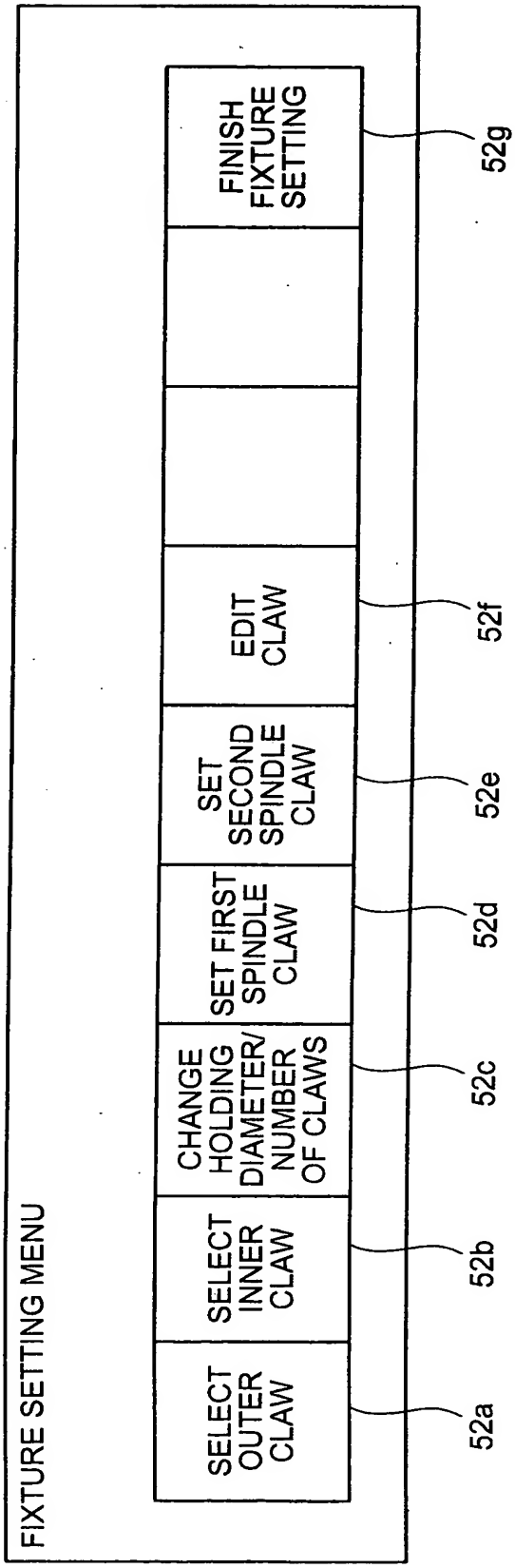
52
FIXTURE SETTING MENU
SELECT OUTER CLAW
SELECT INNER CLAW
CHANGE HOLDING DIAMETER/ NUMBER OF CLAWS
SET FIRST SPINDLE CLAW
SET SECOND SPINDLE CLAW
EDIT CLAW
FINISH FIXTURE SETTING
52a
52b
52c
52d
52e
52f
52g

FIG.27

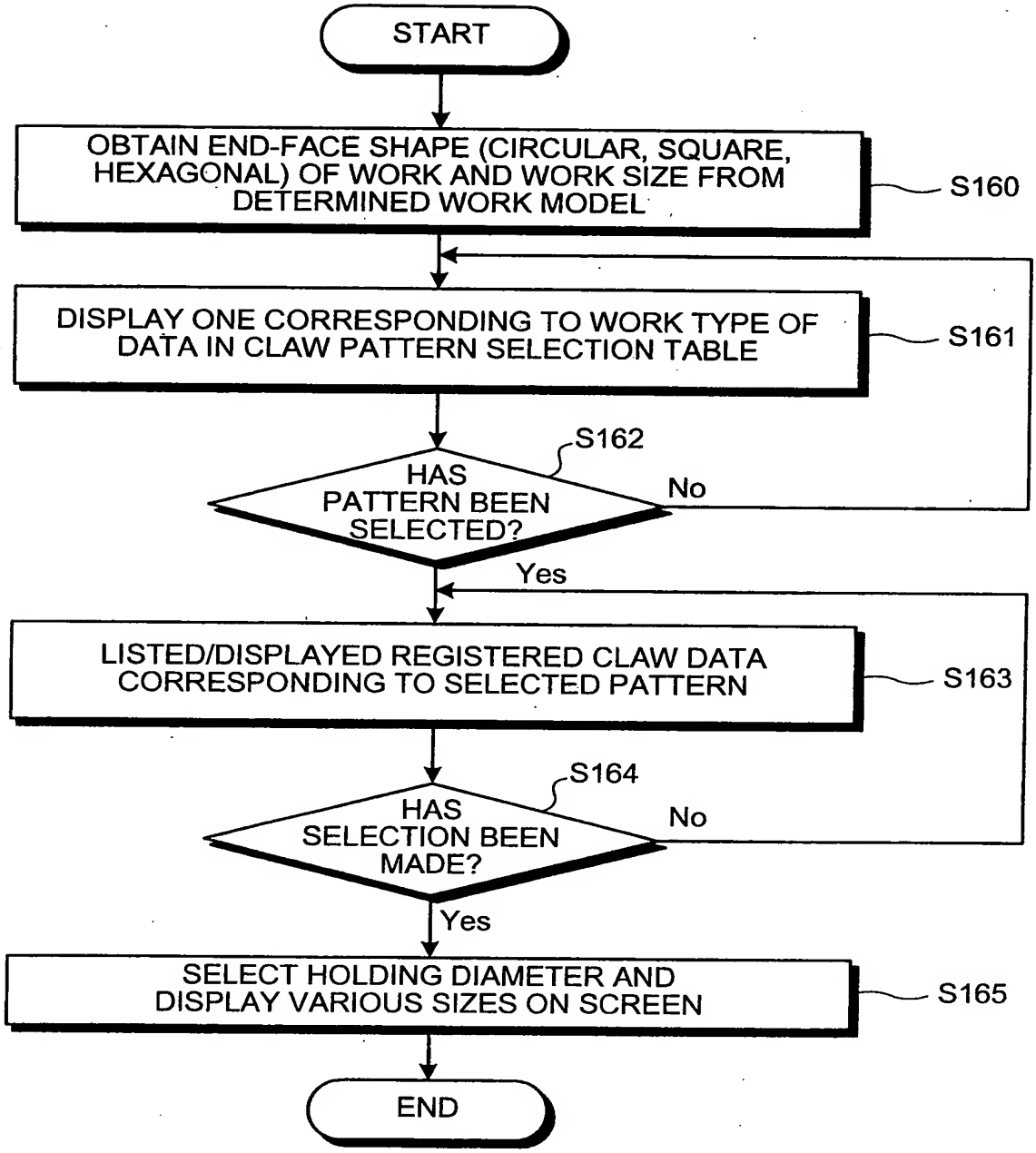
START
OBTAIN END-FACE SHAPE (CIRCULAR, SQUARE, HEXAGONAL) OF WORK AND WORK SIZE FROM DETERMINED WORK MODEL
S160
DISPLAY ONE CORRESPONDING TO WORK TYPE OF DATA IN CLAW PATTERN SELECTION TABLE
S161
S162
HAS PATTERN BEEN SELECTED?
No
Yes
LISTED/DISPLAYED REGISTERED CLAW DATA CORRESPONDING TO SELECTED PATTERN
S163
S164
HAS SELECTION BEEN MADE?
No
Yes
SELECT HOLDING DIAMETER AND DISPLAY VARIOUS SIZES ON SCREEN
S165
END

FIG.28

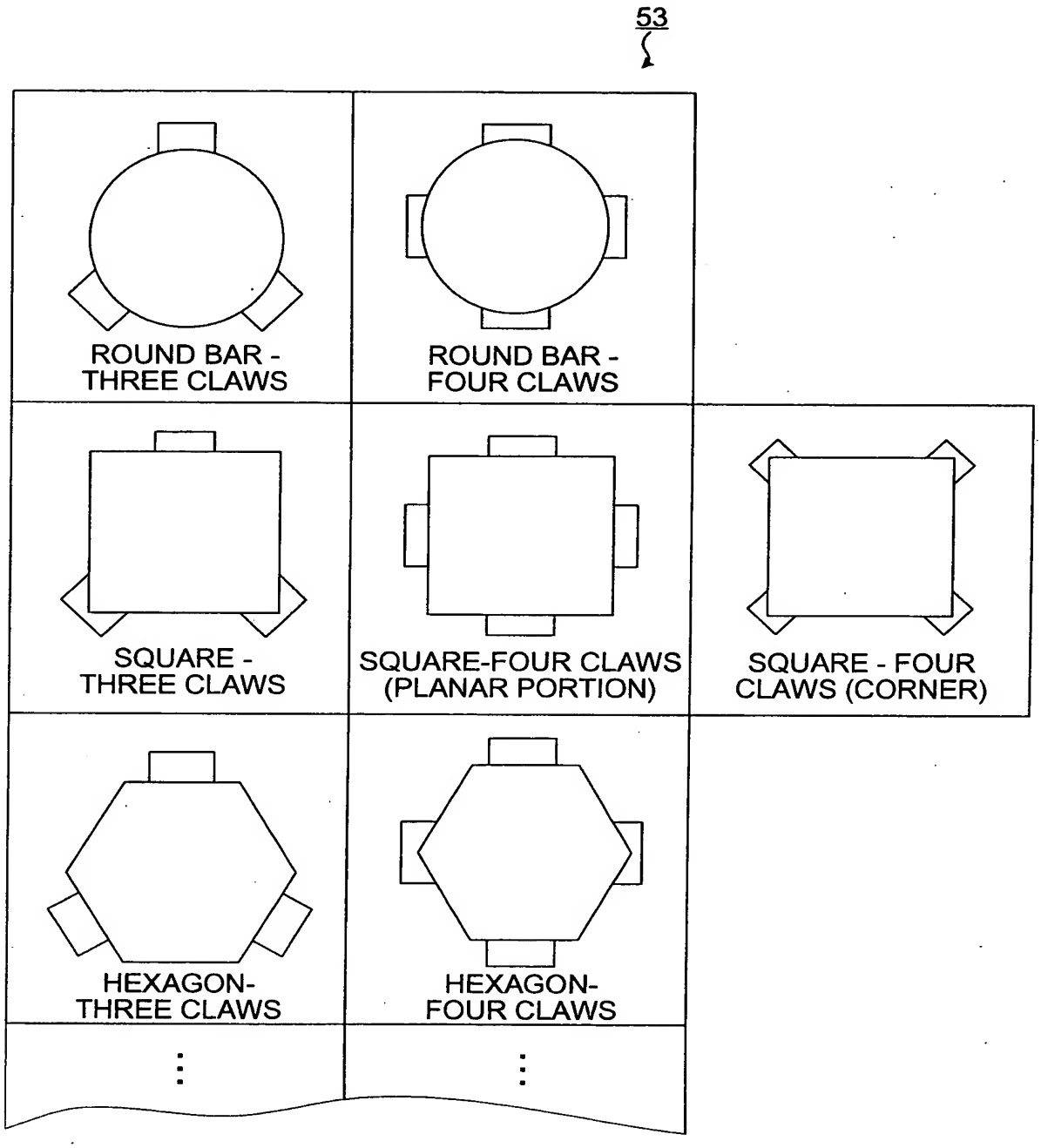
53
ROUND BAR - THREE CLAWS
ROUND BAR - FOUR CLAWS
SQUARE - THREE CLAWS
SQUARE-FOUR CLAWS (PLANAR PORTION)
SQUARE - FOUR CLAWS (CORNER)
HEXAGON- THREE CLAWS
HEXAGON- FOUR CLAWS

FIG.29

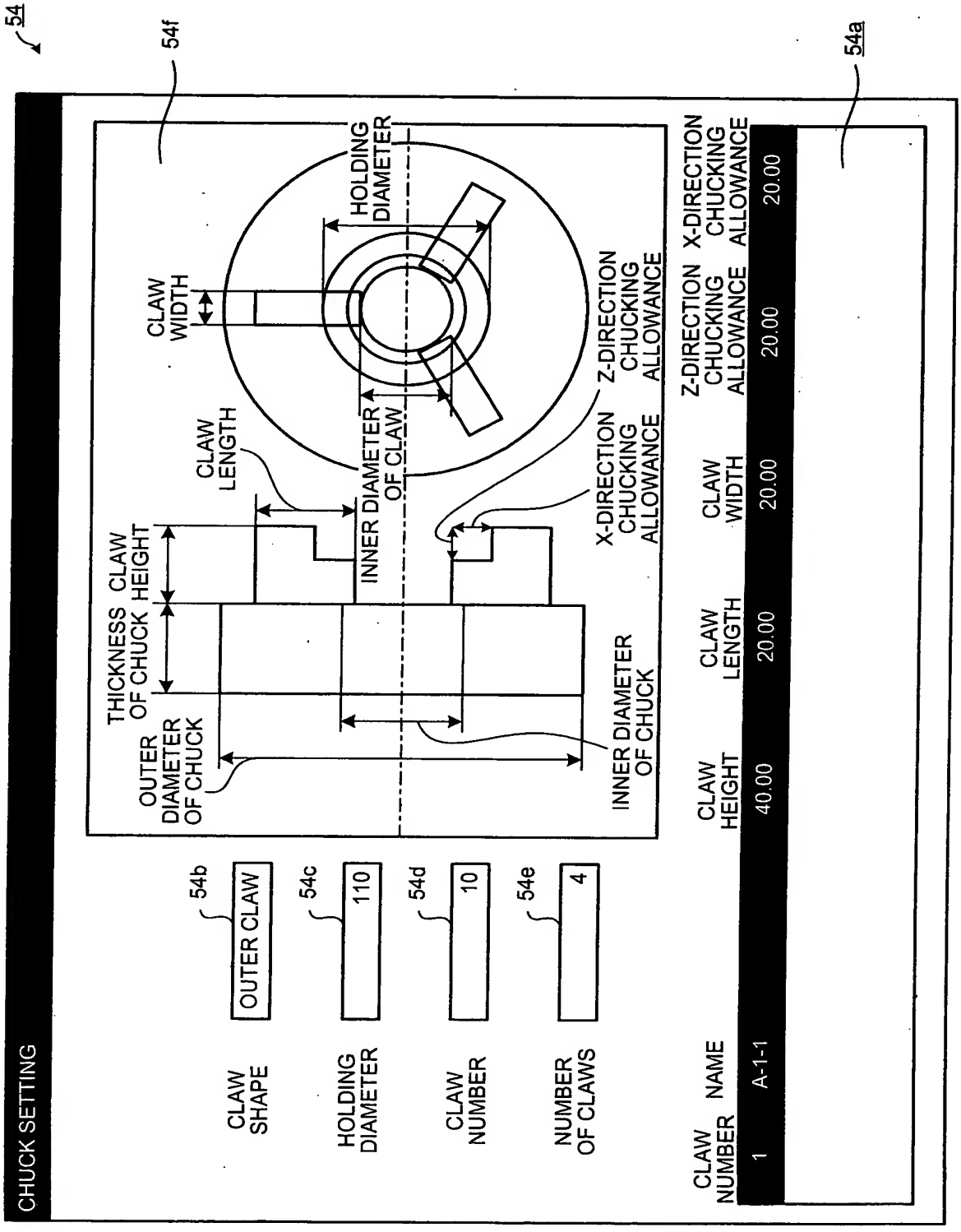
54
54f
54a
CHUCK SETTING
HOLDING DIAMETER
CLAW WIDTH
CLAW LENGTH
INNER DIAMETER OF CLAW
Z-DIRECTION CHUCKING ALLOWANCE
X-DIRECTION CHUCKING ALLOWANCE
THICKNESS OF CHUCK
CLAW HEIGHT
OUTER DIAMETER OF CHUCK
INNER DIAMETER OF CHUCK
54b
OUTER CLAW
CLAW SHAPE
54c
110
HOLDING DIAMETER
54d
10
CLAW NUMBER
54e
4
NUMBER OF CLAWS
CLAW NUMBER
NAME
CLAW HEIGHT
CLAW LENGTH
CLAW WIDTH
Z-DIRECTION CHUCKING ALLOWANCE
X-DIRECTION CHUCKING ALLOWANCE
1
A-1-1
40.00
20.00
20.00
20.00
20.00

FIG.30

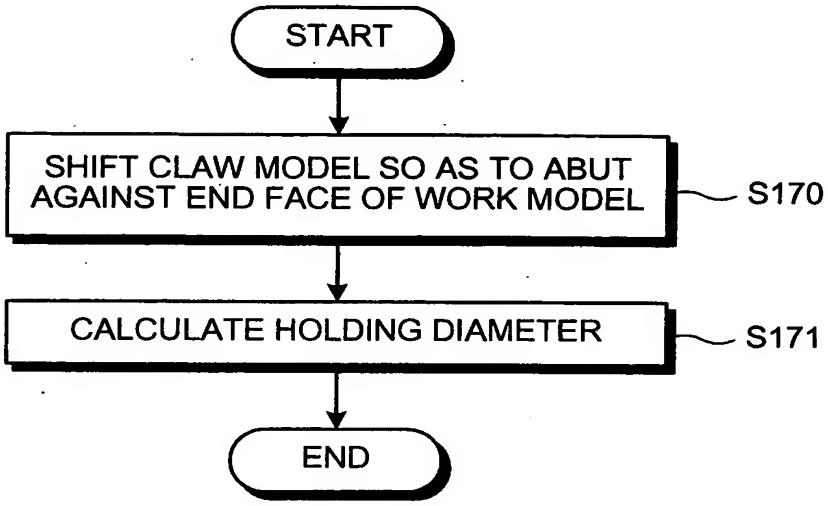
START
SHIFT CLAW MODEL SO AS TO ABUT AGAINST END FACE OF WORK MODEL
S170
CALCULATE HOLDING DIAMETER
S171
END

FIG.31

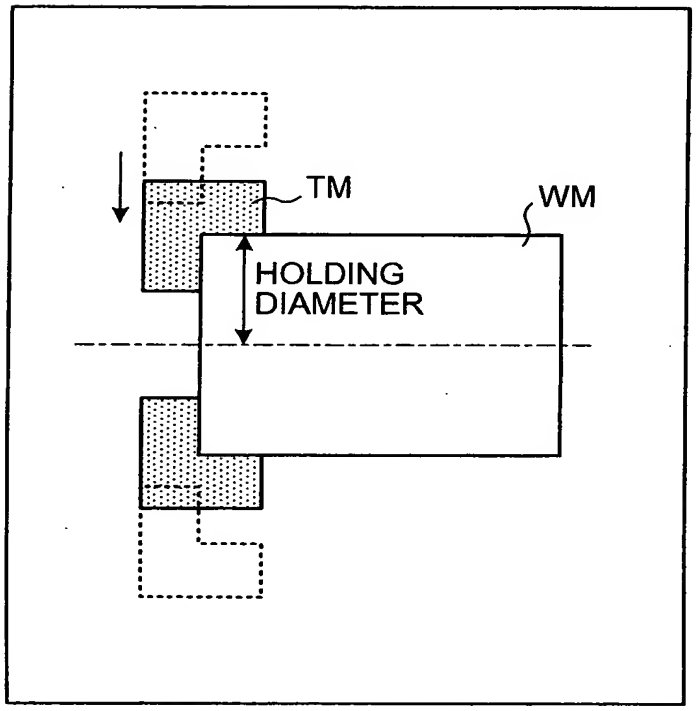
TM
WM
HOLDING DIAMETER

FIG.32

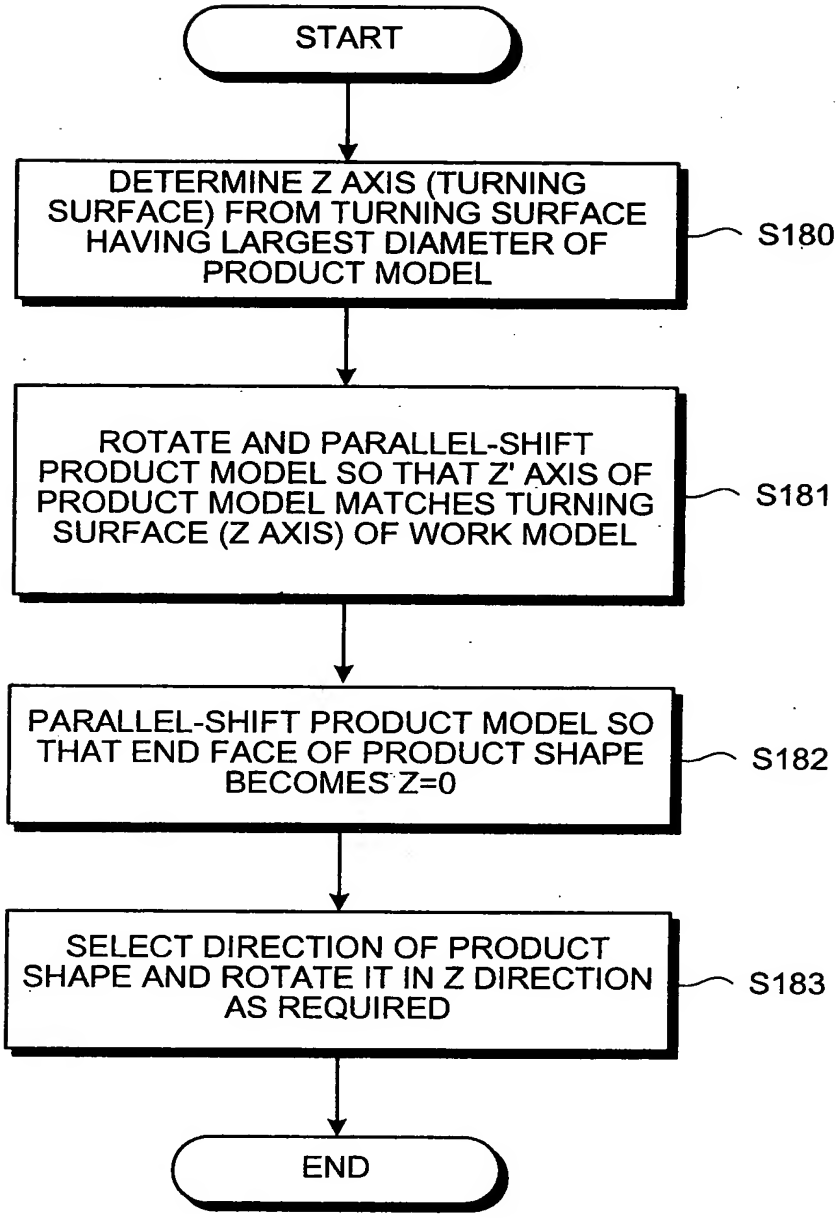
START
DETERMINE Z AXIS (TURNING SURFACE) FROM TURNING SURFACE HAVING LARGEST DIAMETER OF PRODUCT MODEL
S180
ROTATE AND PARALLEL-SHIFT PRODUCT MODEL SO THAT Z' AXIS OF PRODUCT MODEL MATCHES TURNING SURFACE (Z AXIS) OF WORK MODEL
S181
PARALLEL-SHIFT PRODUCT MODEL SO THAT END FACE OF PRODUCT SHAPE BECOMES Z=0
S182
SELECT DIRECTION OF PRODUCT SHAPE AND ROTATE IT IN Z DIRECTION AS REQUIRED
S183
END

FIG.33

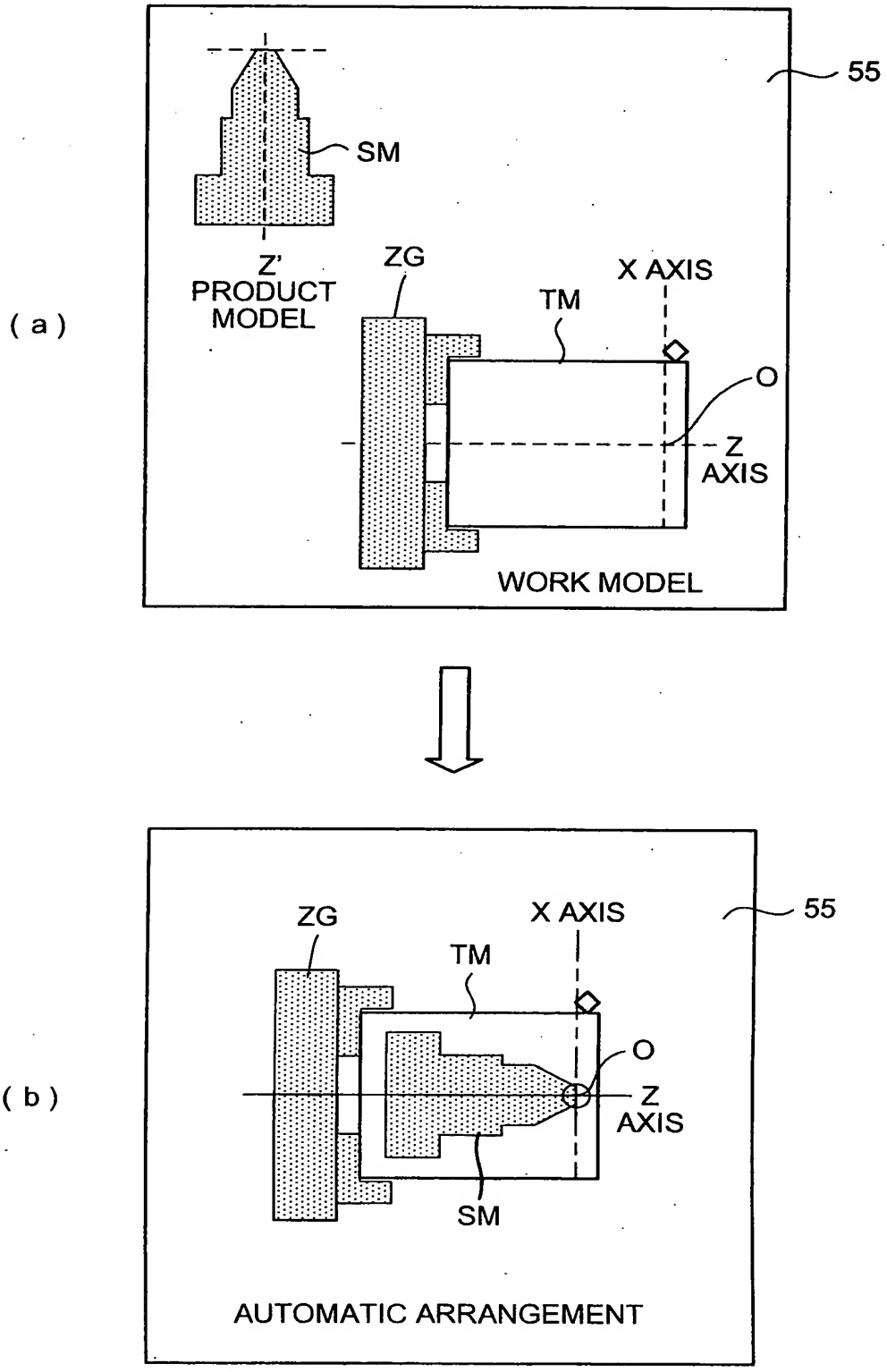
(a)
55
SM
Z'
PRODUCT
MODEL
ZG
TM
X AXIS
O
Z
AXIS
WORK MODEL
(b)
ZG
X AXIS
55
TM
O
Z
AXIS
SM
AUTOMATIC ARRANGEMENT

FIG.34A

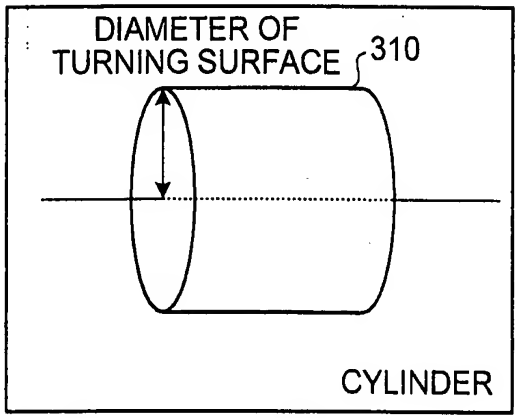

FIG.34B

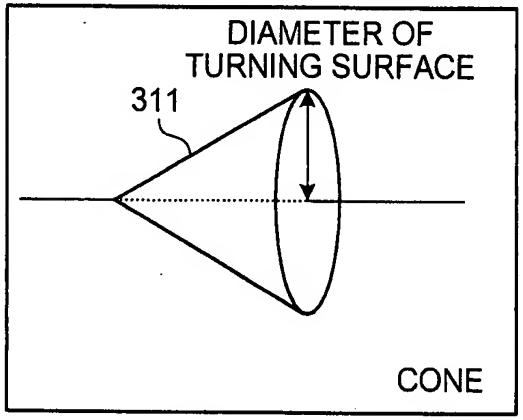

FIG.34E

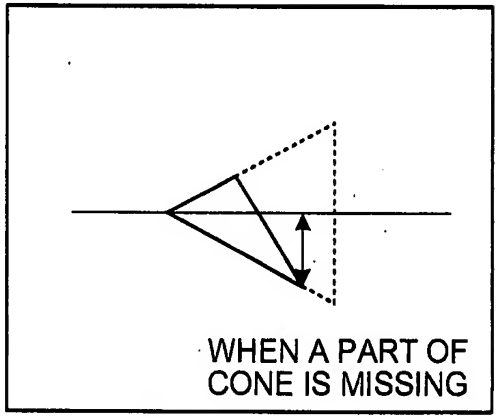

FIG.34C

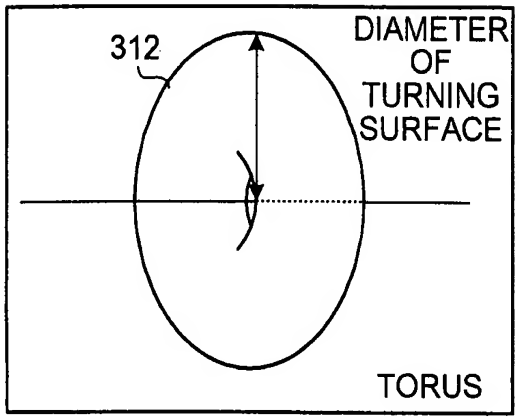

FIG.34D

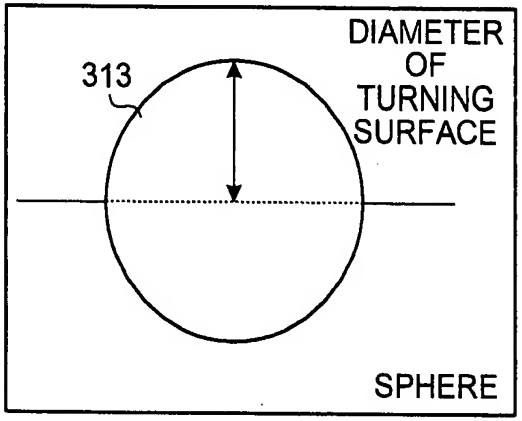

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FIG.35

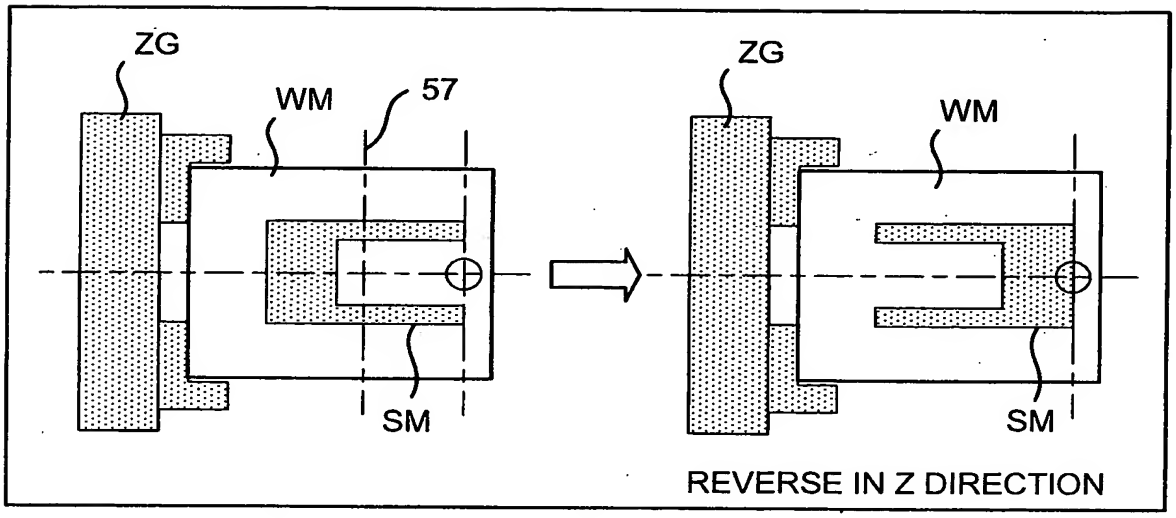

FIG.36

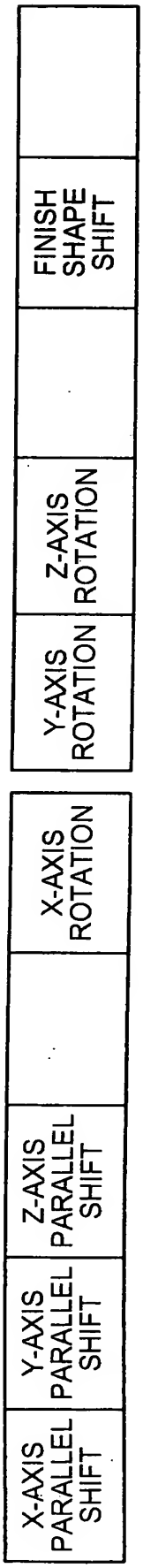
X-AXIS PARALLEL SHIFT
Y-AXIS PARALLEL SHIFT
Z-AXIS PARALLEL SHIFT
X-AXIS ROTATION
Y-AXIS ROTATION
Z-AXIS ROTATION
FINISH SHAPE SHIFT

FIG.37

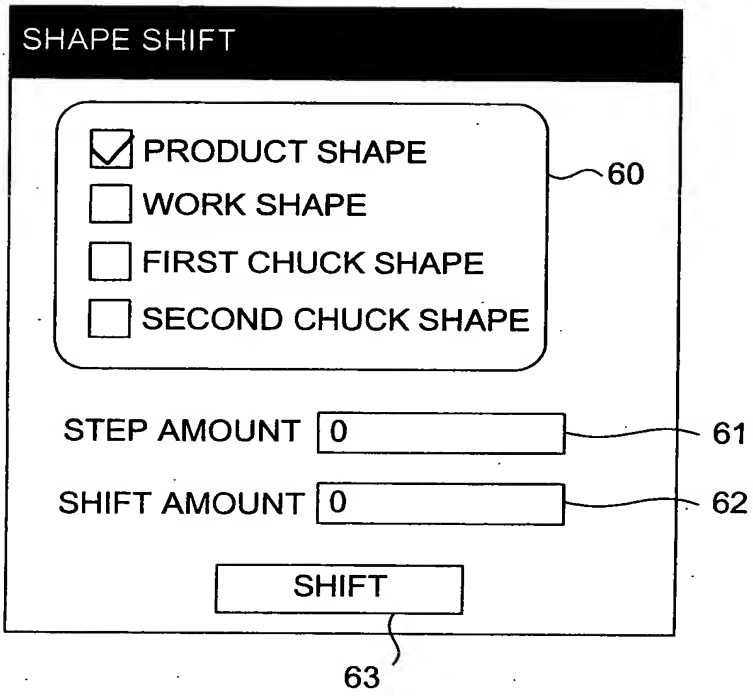
SHAPE SHIFT
PRODUCT SHAPE
WORK SHAPE
FIRST CHUCK SHAPE
SECOND CHUCK SHAPE
60
STEP AMOUNT
0
61
SHIFT AMOUNT
0
62
SHIFT
63

FIG.38

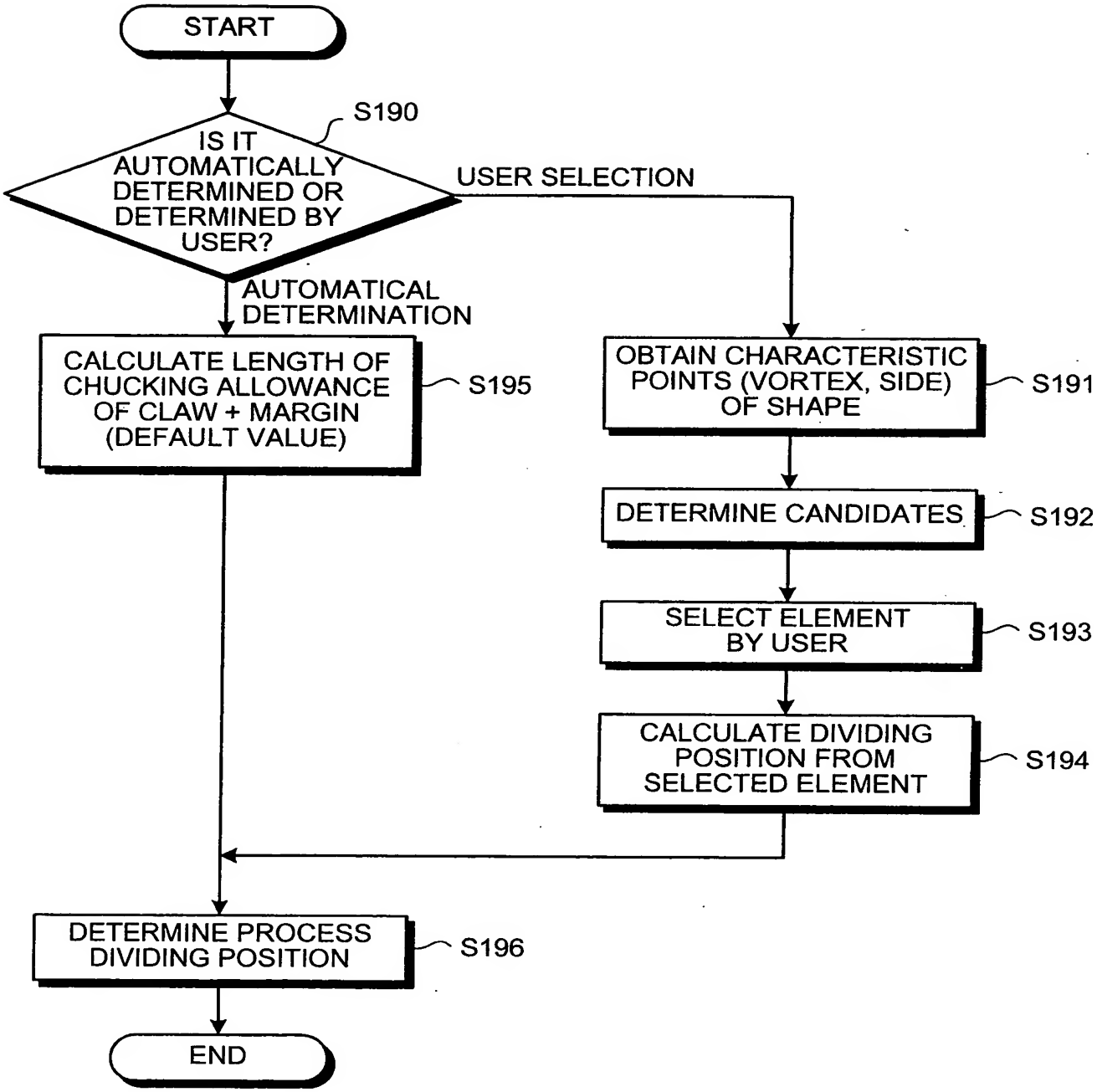
START
S190
IS IT AUTOMATICALLY DETERMINED OR DETERMINED BY USER?
USER SELECTION
AUTOMATICAL DETERMINATION
CALCULATE LENGTH OF CHUCKING ALLOWANCE OF CLAW + MARGIN (DEFAULT VALUE)
S195
OBTAIN CHARACTERISTIC POINTS (VORTEX, SIDE) OF SHAPE
S191
DETERMINE CANDIDATES
S192
SELECT ELEMENT BY USER
S193
CALCULATE DIVIDING POSITION FROM SELECTED ELEMENT
S194
DETERMINE PROCESS DIVIDING POSITION
S196
END

FIG.39

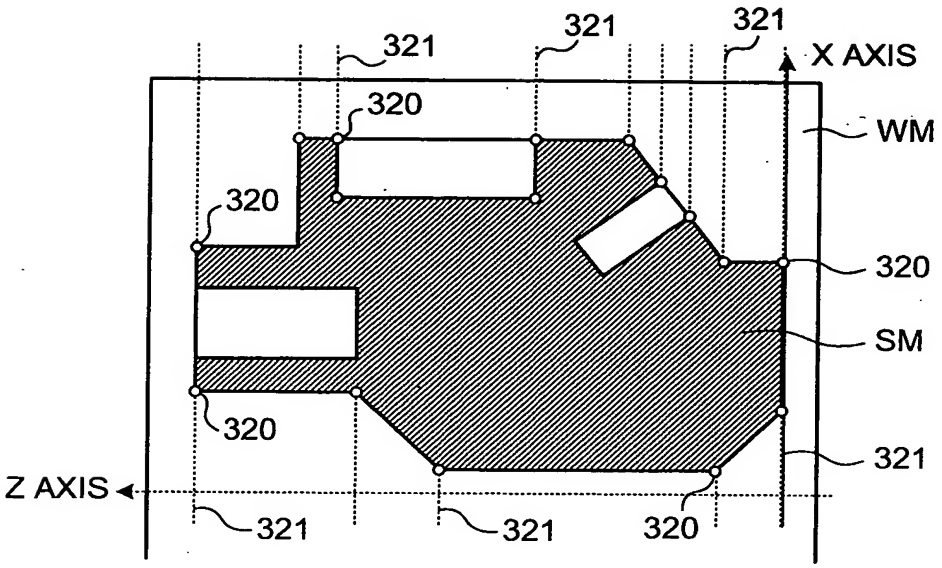
321
321
321
X AXIS
320
WM
320
320
SM
320
321
Z AXIS
321
321
320

FIG.40

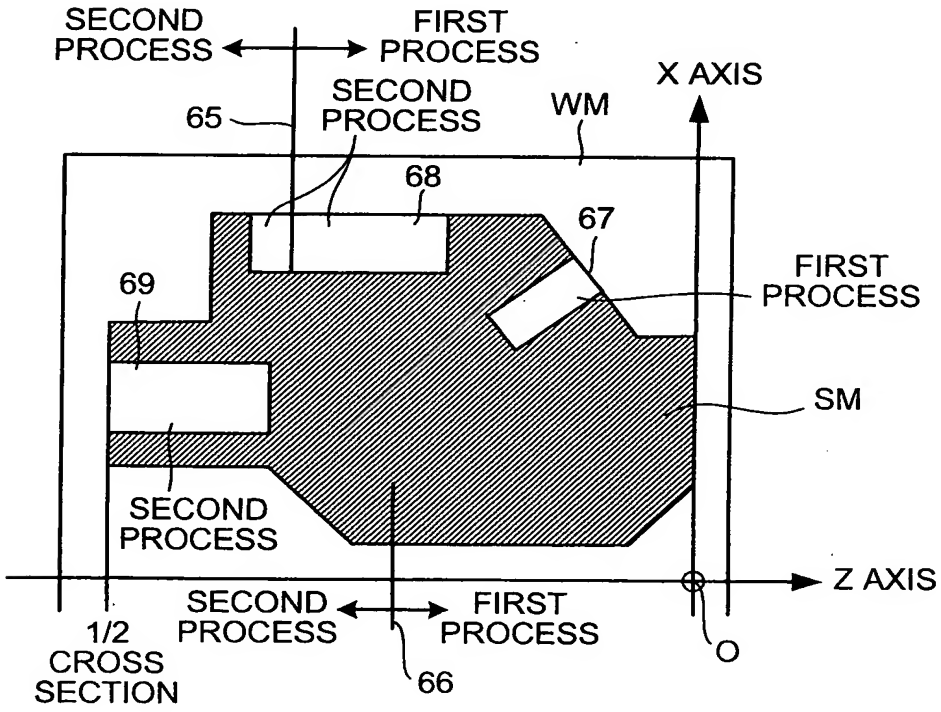
SECOND PROCESS
FIRST PROCESS
X AXIS
65
SECOND PROCESS
WM
68
67
69
FIRST PROCESS
SM
SECOND PROCESS
Z AXIS
SECOND PROCESS
FIRST PROCESS
1/2 CROSS SECTION
66
O

FIG.41

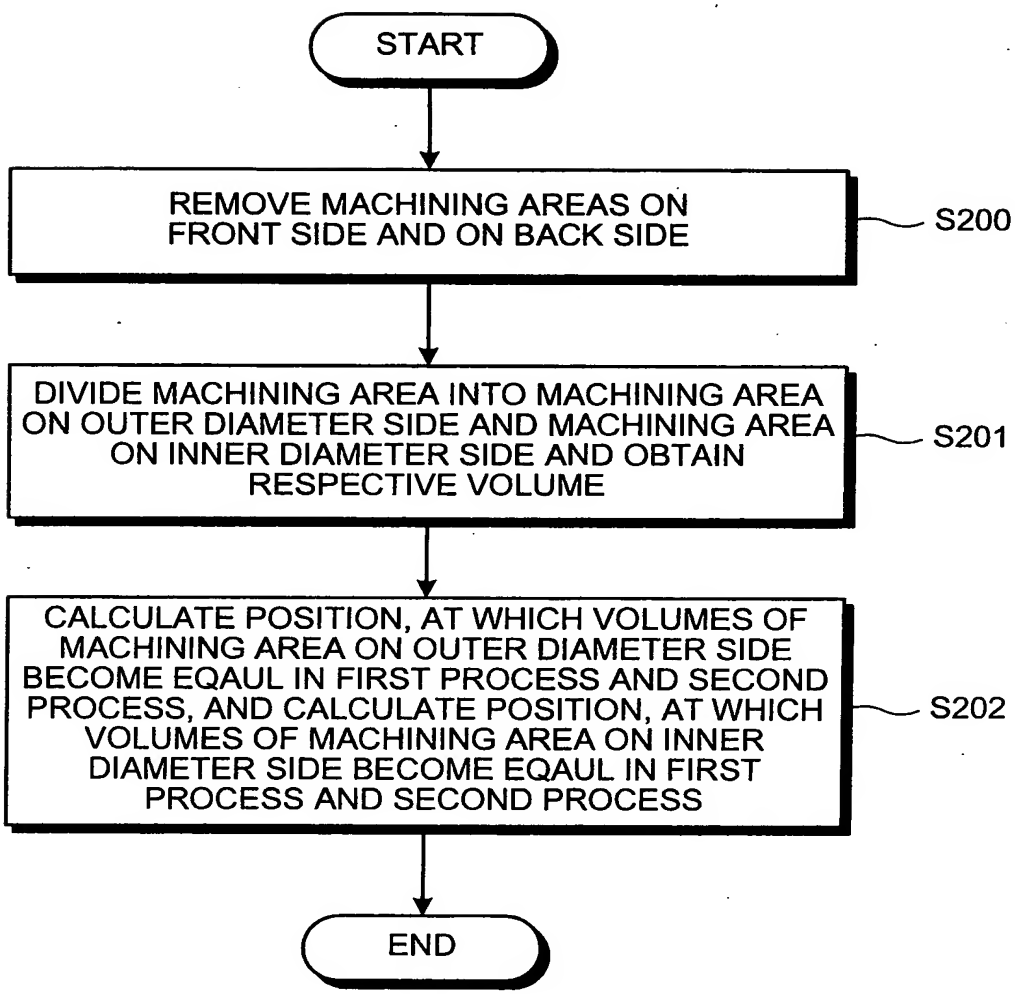
START
REMOVE MACHINING AREAS ON FRONT SIDE AND ON BACK SIDE
S200
DIVIDE MACHINING AREA INTO MACHINING AREA ON OUTER DIAMETER SIDE AND MACHINING AREA ON INNER DIAMETER SIDE AND OBTAIN RESPECTIVE VOLUME
S201
CALCULATE POSITION, AT WHICH VOLUMES OF MACHINING AREA ON OUTER DIAMETER SIDE BECOME EQAUL IN FIRST PROCESS AND SECOND PROCESS, AND CALCULATE POSITION, AT WHICH VOLUMES OF MACHINING AREA ON INNER DIAMETER SIDE BECOME EQAUL IN FIRST PROCESS AND SECOND PROCESS
S202
END

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FIG.42A

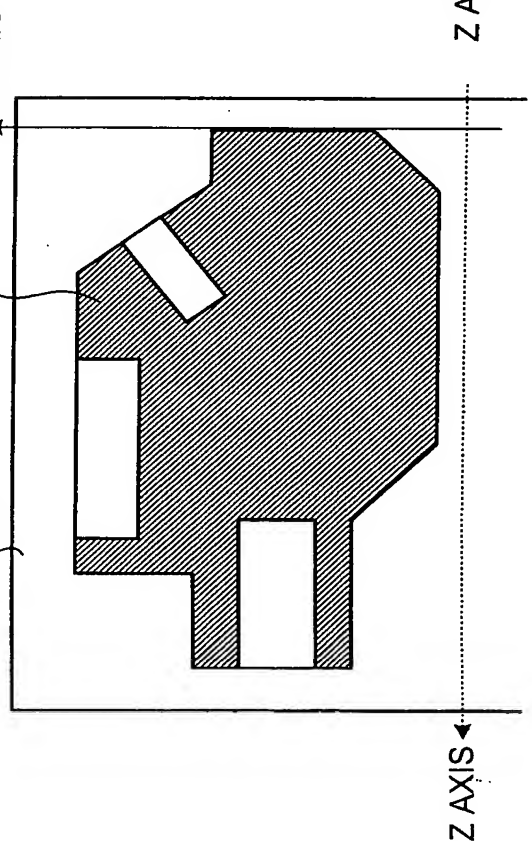


FIG.42B

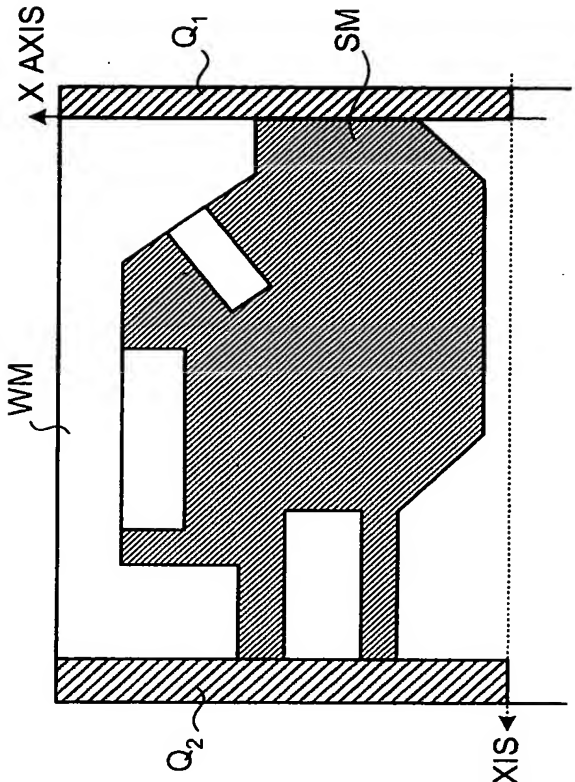


FIG.42C

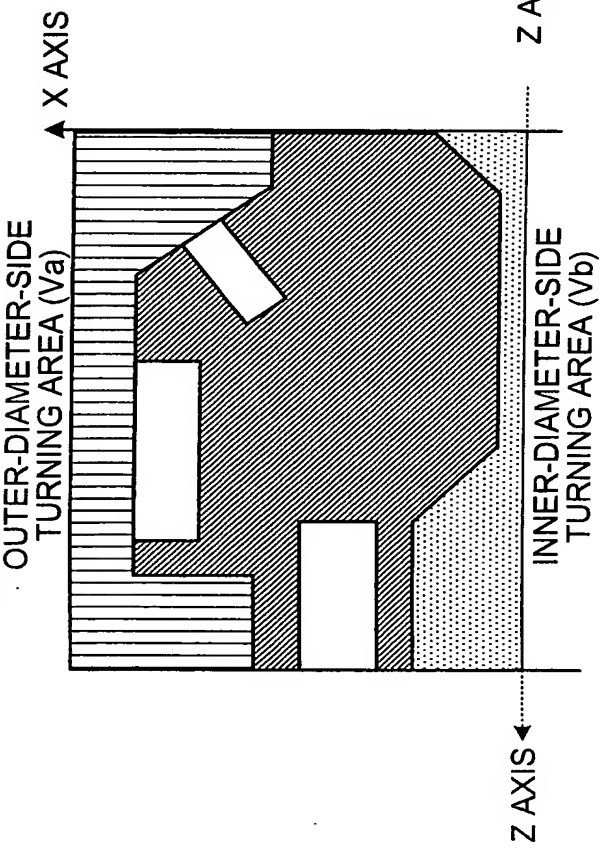


FIG.42D

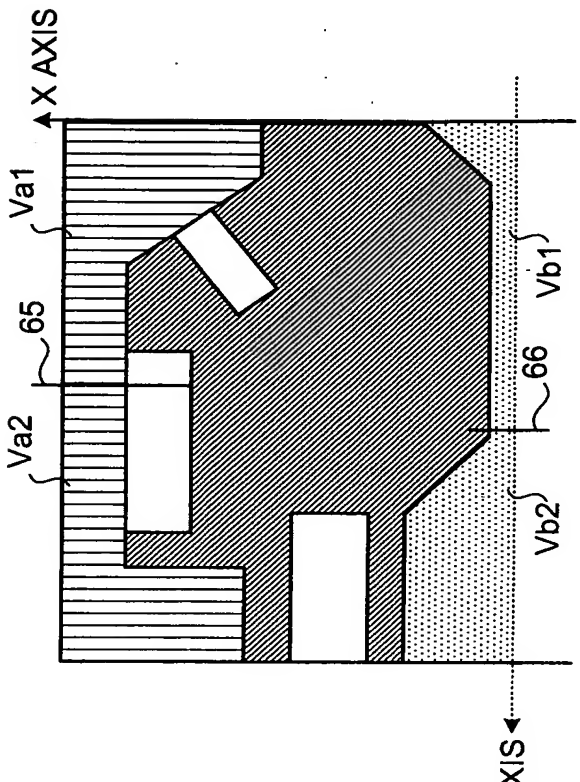


FIG.43

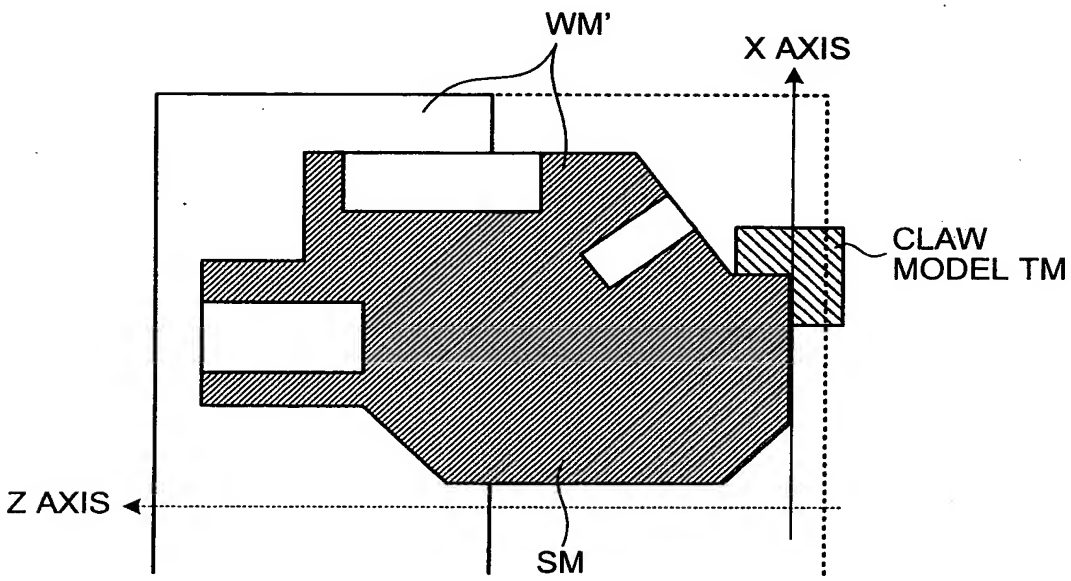
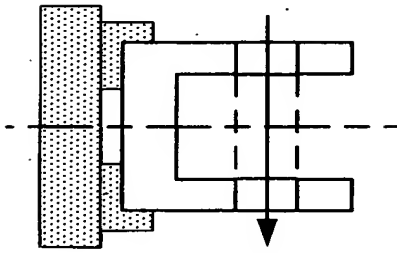
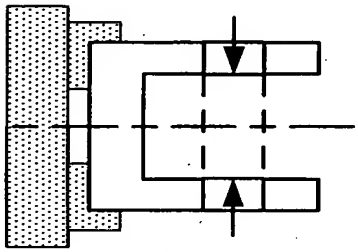


FIG.44A



THROUGH HOLE

FIG.44B



TWO HOLES

FIG.45

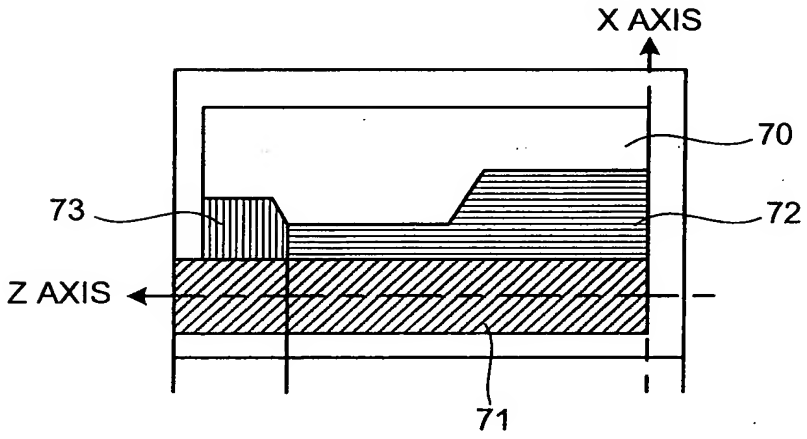


FIG.46

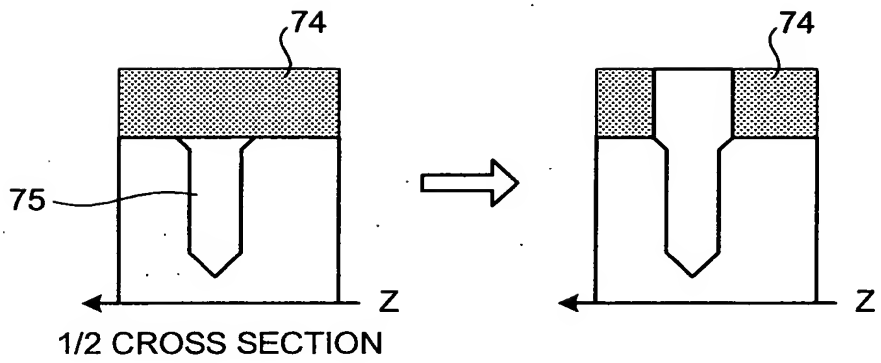

74
75
Z
1/2 CROSS SECTION
74
Z
(a)
(b)

FIG.47

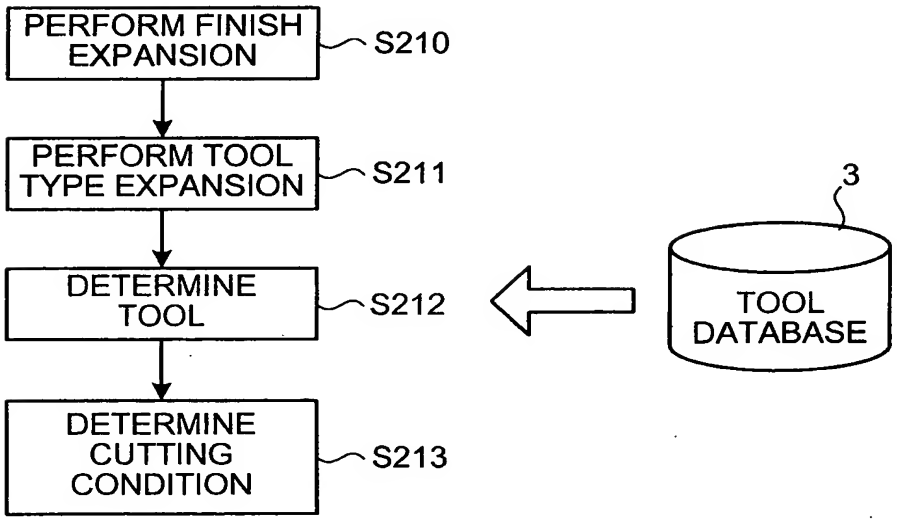

PERFORM FINISH EXPANSION
S210
PERFORM TOOL TYPE EXPANSION
S211
DETERMINE TOOL
S212
DETERMINE CUTTING CONDITION
S213
3
TOOL DATABASE

FIG.48

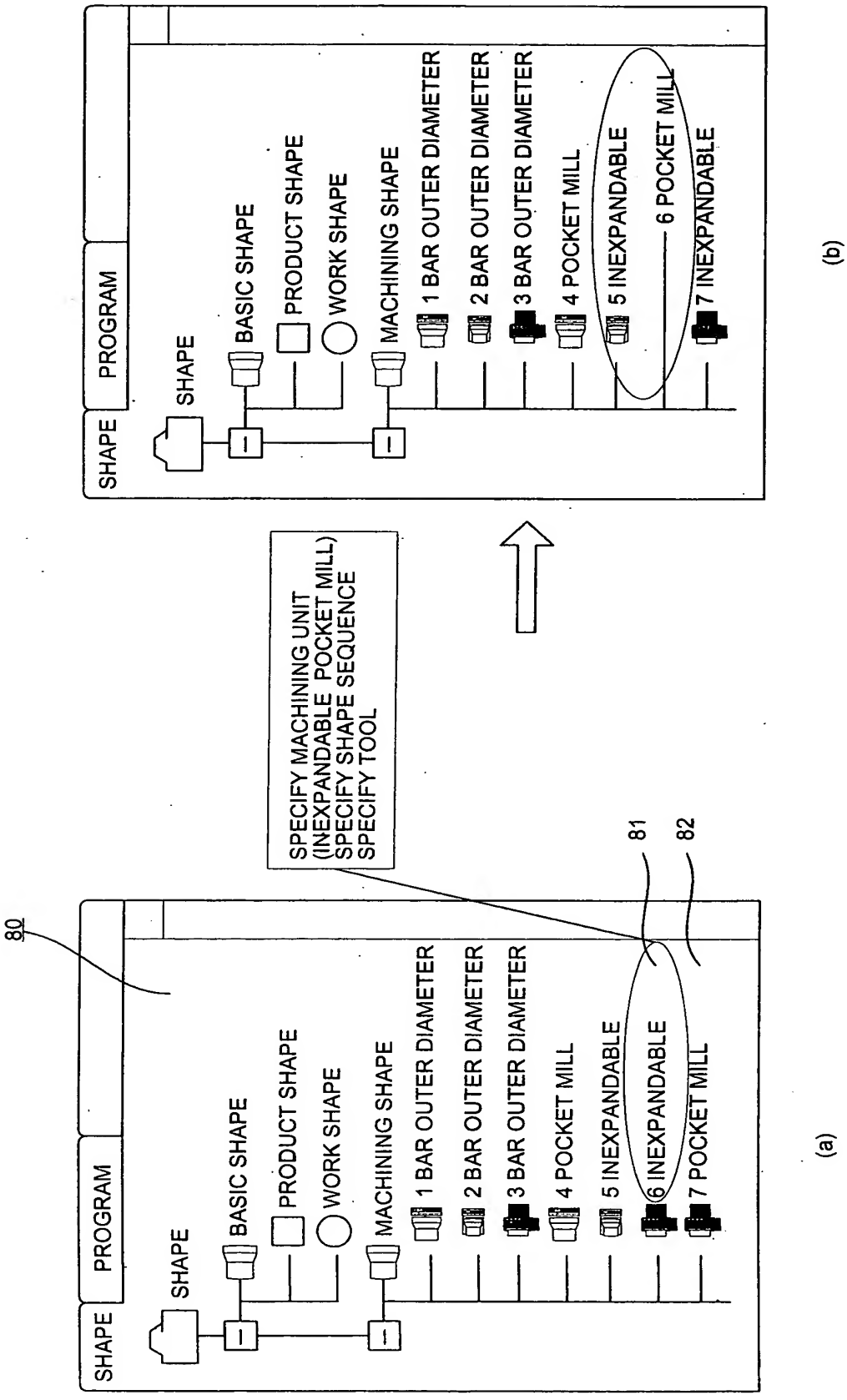

SHAPE
PROGRAM
SHAPE
BASIC SHAPE
PRODUCT SHAPE
WORK SHAPE
MACHINING SHAPE
1 BAR OUTER DIAMETER
2 BAR OUTER DIAMETER
3 BAR OUTER DIAMETER
4 POCKET MILL
5 INEXPANDABLE
6 POCKET MILL
7 INEXPANDABLE
(b)
SPECIFY MACHINING UNIT
(INEXPANDABLE POCKET MILL)
SPECIFY SHAPE SEQUENCE
SPECIFY TOOL
80
81
82
SHAPE
PROGRAM
SHAPE
BASIC SHAPE
PRODUCT SHAPE
WORK SHAPE
MACHINING SHAPE
1 BAR OUTER DIAMETER
2 BAR OUTER DIAMETER
3 BAR OUTER DIAMETER
4 POCKET MILL
5 INEXPANDABLE
6 INEXPANDABLE
7 POCKET MILL
(a)

FIG.49

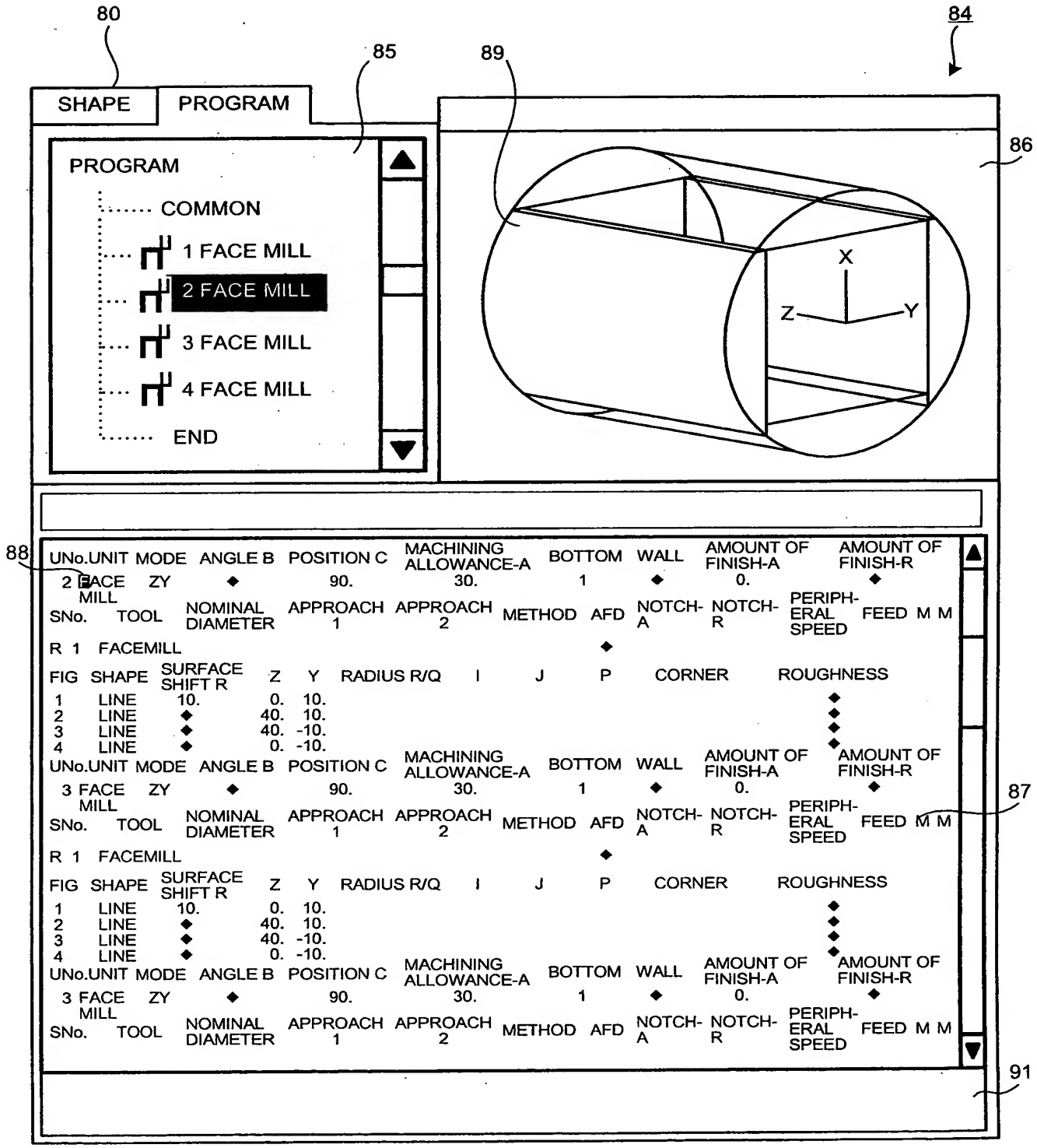

80
84
85
89
SHAPE
PROGRAM
PROGRAM
COMMON
1 FACE MILL
2 FACE MILL
3 FACE MILL
4 FACE MILL
END
86
X
Z
Y
88
UNo.UNIT MODE ANGLE B POSITION C MACHINING ALLOWANCE-A BOTTOM WALL AMOUNT OF FINISH-A AMOUNT OF FINISH-R
2 FACE MILL ZY ◆ 90. 30. 1 ◆ 0. ◆
SNo. TOOL NOMINAL DIAMETER APPROACH 1 APPROACH 2 METHOD AFD NOTCH-A NOTCH-R PERIPH-ERAL SPEED FEED M M
R 1 FACEMILL ◆
FIG SHAPE SURFACE SHIFT R Z Y RADIUS R/Q I J P CORNER ROUGHNESS
1 LINE 10. 0. 10. ◆
2 LINE ◆ 40. 10. ◆
3 LINE ◆ 40. -10. ◆
4 LINE ◆ 0. -10. ◆
UNo.UNIT MODE ANGLE B POSITION C MACHINING ALLOWANCE-A BOTTOM WALL AMOUNT OF FINISH-A AMOUNT OF FINISH-R
3 FACE MILL ZY ◆ 90. 30. 1 ◆ 0. ◆
SNo. TOOL NOMINAL DIAMETER APPROACH 1 APPROACH 2 METHOD AFD NOTCH-A NOTCH-R PERIPH-ERAL SPEED FEED M M
R 1 FACEMILL ◆
FIG SHAPE SURFACE SHIFT R Z Y RADIUS R/Q I J P CORNER ROUGHNESS
1 LINE 10. 0. 10. ◆
2 LINE ◆ 40. 10. ◆
3 LINE ◆ 40. -10. ◆
4 LINE ◆ 0. -10. ◆
UNo.UNIT MODE ANGLE B POSITION C MACHINING ALLOWANCE-A BOTTOM WALL AMOUNT OF FINISH-A AMOUNT OF FINISH-R
3 FACE MILL ZY ◆ 90. 30. 1 ◆ 0. ◆
SNo. TOOL NOMINAL DIAMETER APPROACH 1 APPROACH 2 METHOD AFD NOTCH-A NOTCH-R PERIPH-ERAL SPEED FEED M M
87
91

FIG.50

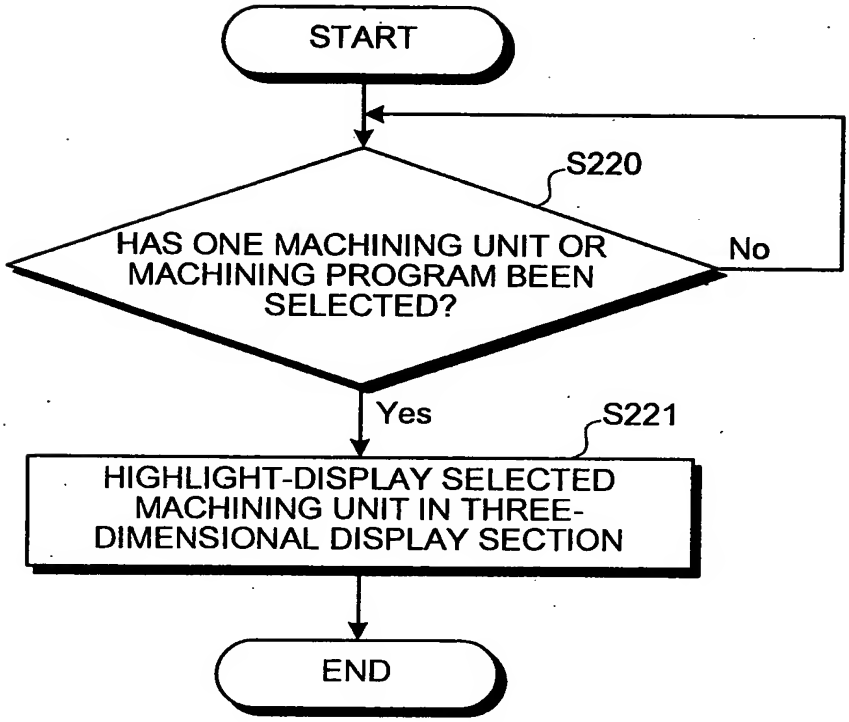


FIG.51A

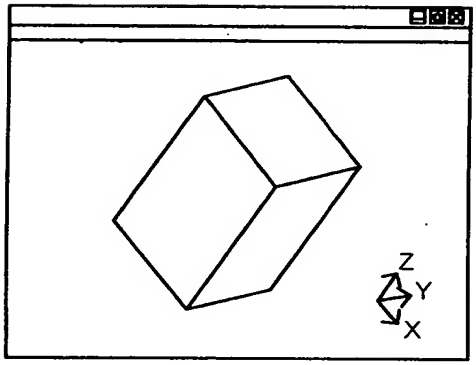


FIG.51B

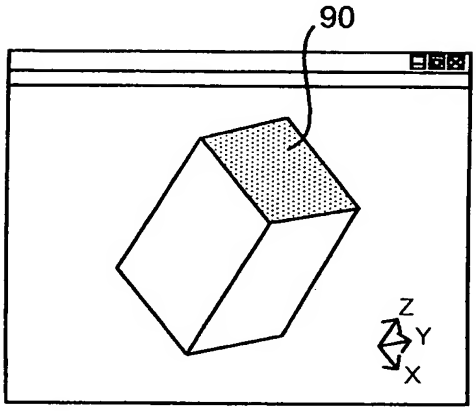


FIG.52

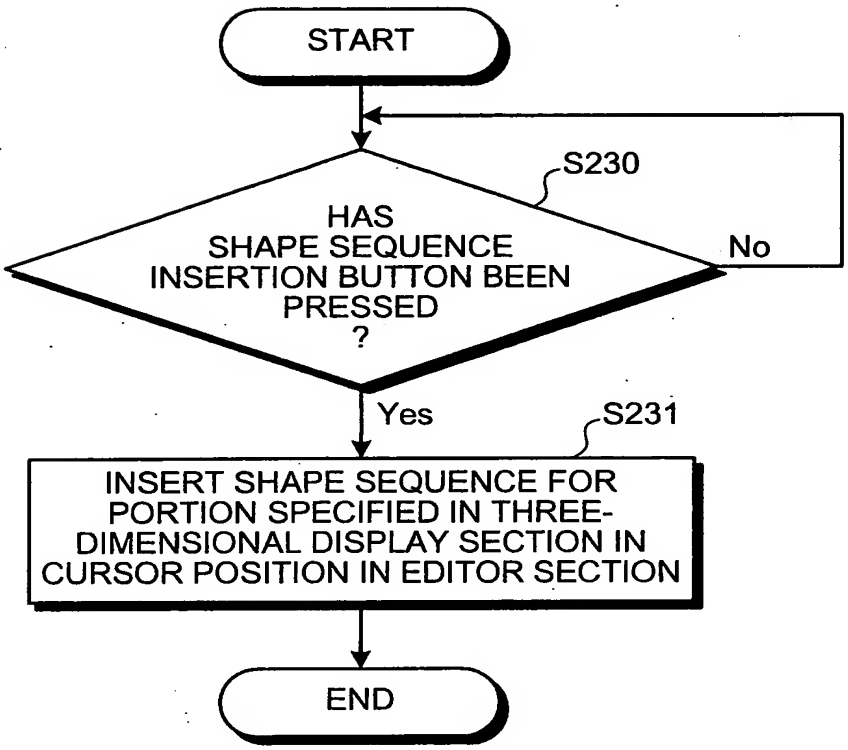

START
S230
HAS SHAPE SEQUENCE INSERTION BUTTON BEEN PRESSED ?
No
Yes
S231
INSERT SHAPE SEQUENCE FOR PORTION SPECIFIED IN THREE-DIMENSIONAL DISPLAY SECTION IN CURSOR POSITION IN EDITOR SECTION
END

FIG.53

UNIT INEXPANDABLE		MODE /Y								
FIG	SHAPE	SURFACE SHIFT Z	SURFACE SHIFT R	X	Y	RADIUS R/	I	J	ANGLE B	ANGLE C
1	LINE (SUPPORT)	0	0	18.487	-29.602				0	0
2	LINE	◆	◆	18.487	-18.5				◆	◆
3	LINE	◆	◆	-18.487	-18.5				◆	◆
4	LINE	◆	◆	-18.487	-29.602				◆	◆
5	LINE	◆	◆	18.487	-29.602				◆	◆

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FIG.54

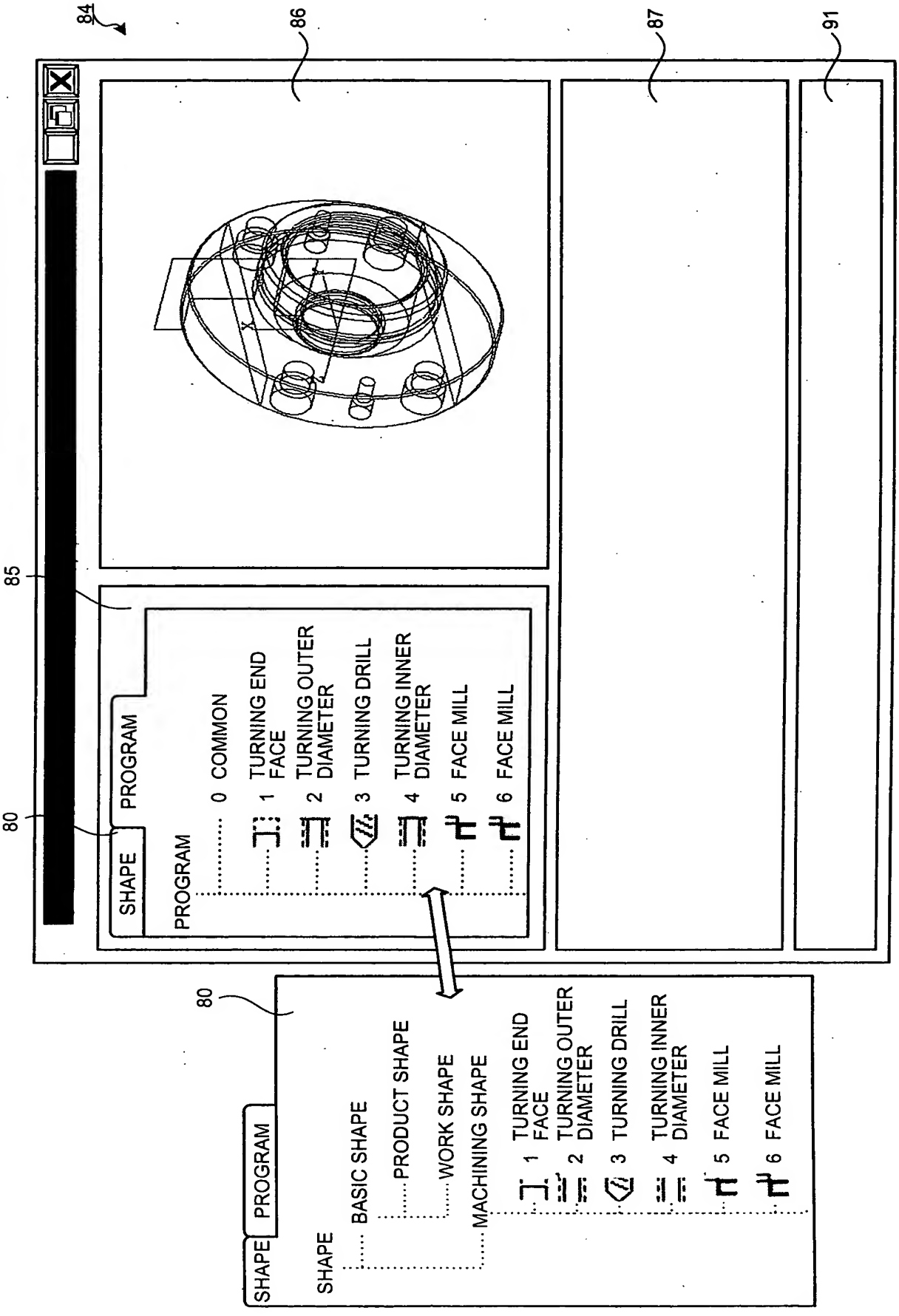

84
86
87
91
85
80
SHAPE
PROGRAM
PROGRAM
0 COMMON
1 TURNING END FACE
2 TURNING OUTER DIAMETER
3 TURNING DRILL
4 TURNING INNER DIAMETER
5 FACE MILL
6 FACE MILL
80
SHAPE
PROGRAM
SHAPE
BASIC SHAPE
PRODUCT SHAPE
WORK SHAPE
MACHINING SHAPE
1 TURNING END FACE
2 TURNING OUTER DIAMETER
3 TURNING DRILL
4 TURNING INNER DIAMETER
5 FACE MILL
6 FACE MILL

FIG.55

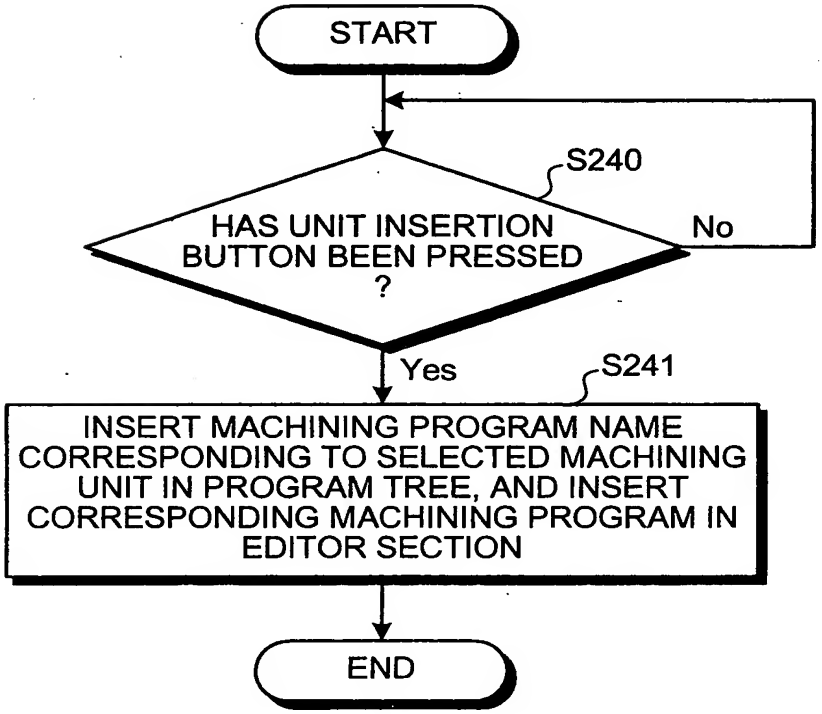

START
S240
HAS UNIT INSERTION BUTTON BEEN PRESSED ?
No
Yes
S241
INSERT MACHINING PROGRAM NAME CORRESPONDING TO SELECTED MACHINING UNIT IN PROGRAM TREE, AND INSERT CORRESPONDING MACHINING PROGRAM IN EDITOR SECTION
END

FIG.56

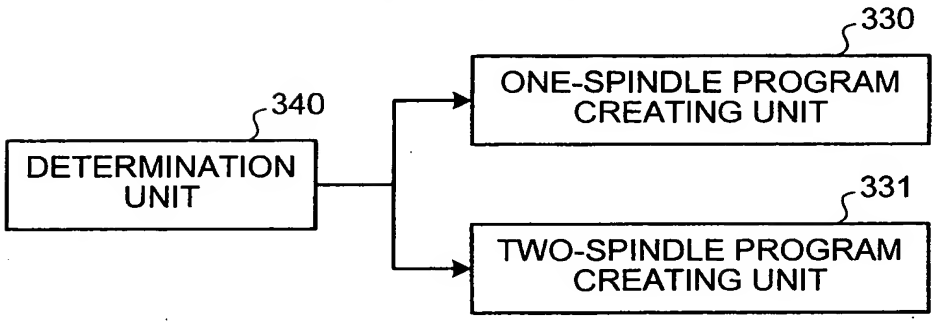
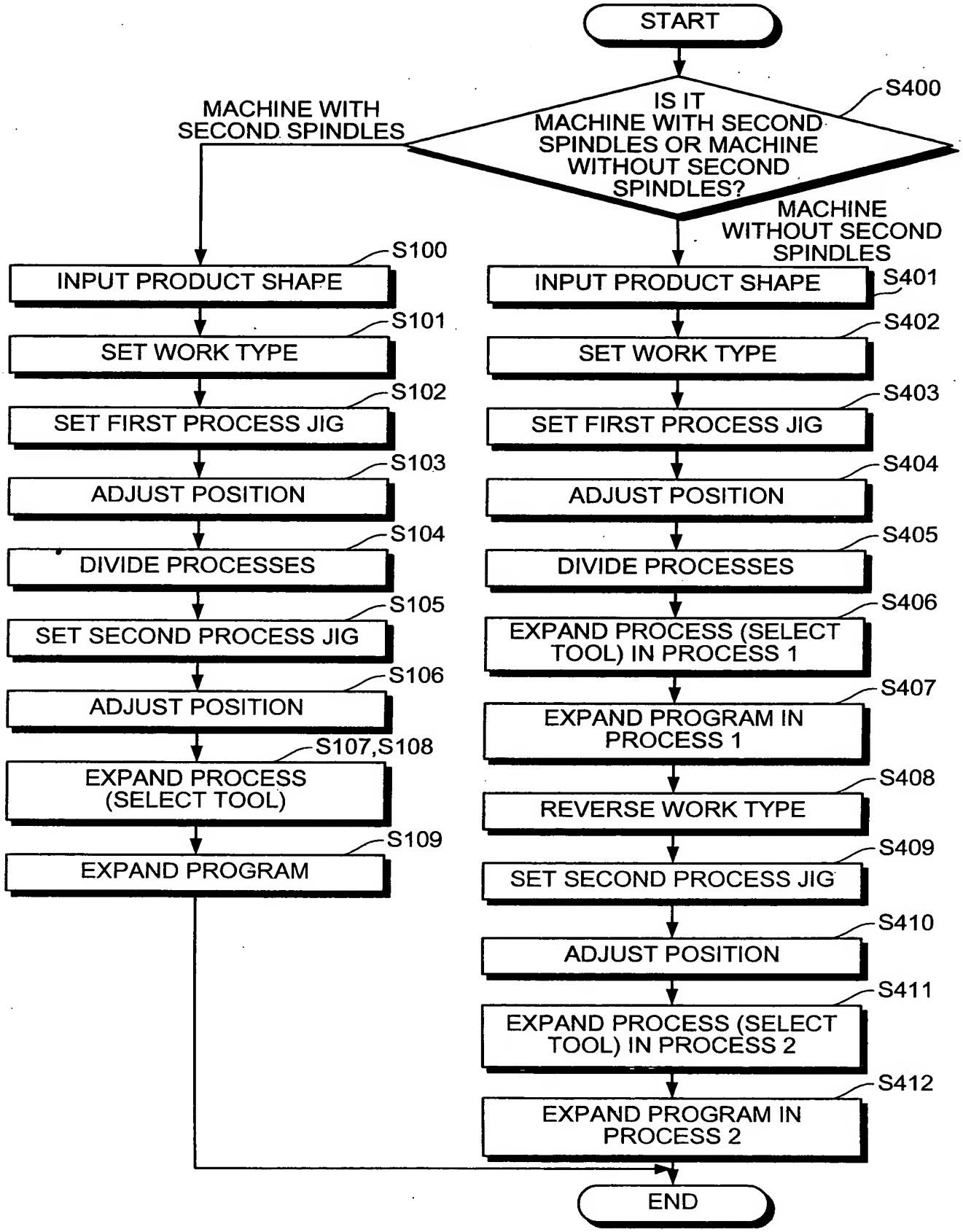

330
ONE-SPINDLE PROGRAM CREATING UNIT
340
DETERMINATION UNIT
331
TWO-SPINDLE PROGRAM CREATING UNIT

FIG.57


START
IS IT MACHINE WITH SECOND SPINDLES OR MACHINE WITHOUT SECOND SPINDLES?
S400
MACHINE WITH SECOND SPINDLES
MACHINE WITHOUT SECOND SPINDLES
INPUT PRODUCT SHAPE
S100
SET WORK TYPE
S101
SET FIRST PROCESS JIG
S102
ADJUST POSITION
S103
DIVIDE PROCESSES
S104
SET SECOND PROCESS JIG
S105
ADJUST POSITION
S106
EXPAND PROCESS (SELECT TOOL)
S107,S108
EXPAND PROGRAM
S109
INPUT PRODUCT SHAPE
S401
SET WORK TYPE
S402
SET FIRST PROCESS JIG
S403
ADJUST POSITION
S404
DIVIDE PROCESSES
S405
EXPAND PROCESS (SELECT TOOL) IN PROCESS 1
S406
EXPAND PROGRAM IN PROCESS 1
S407
REVERSE WORK TYPE
S408
SET SECOND PROCESS JIG
S409
ADJUST POSITION
S410
EXPAND PROCESS (SELECT TOOL) IN PROCESS 2
S411
EXPAND PROGRAM IN PROCESS 2
S412
END